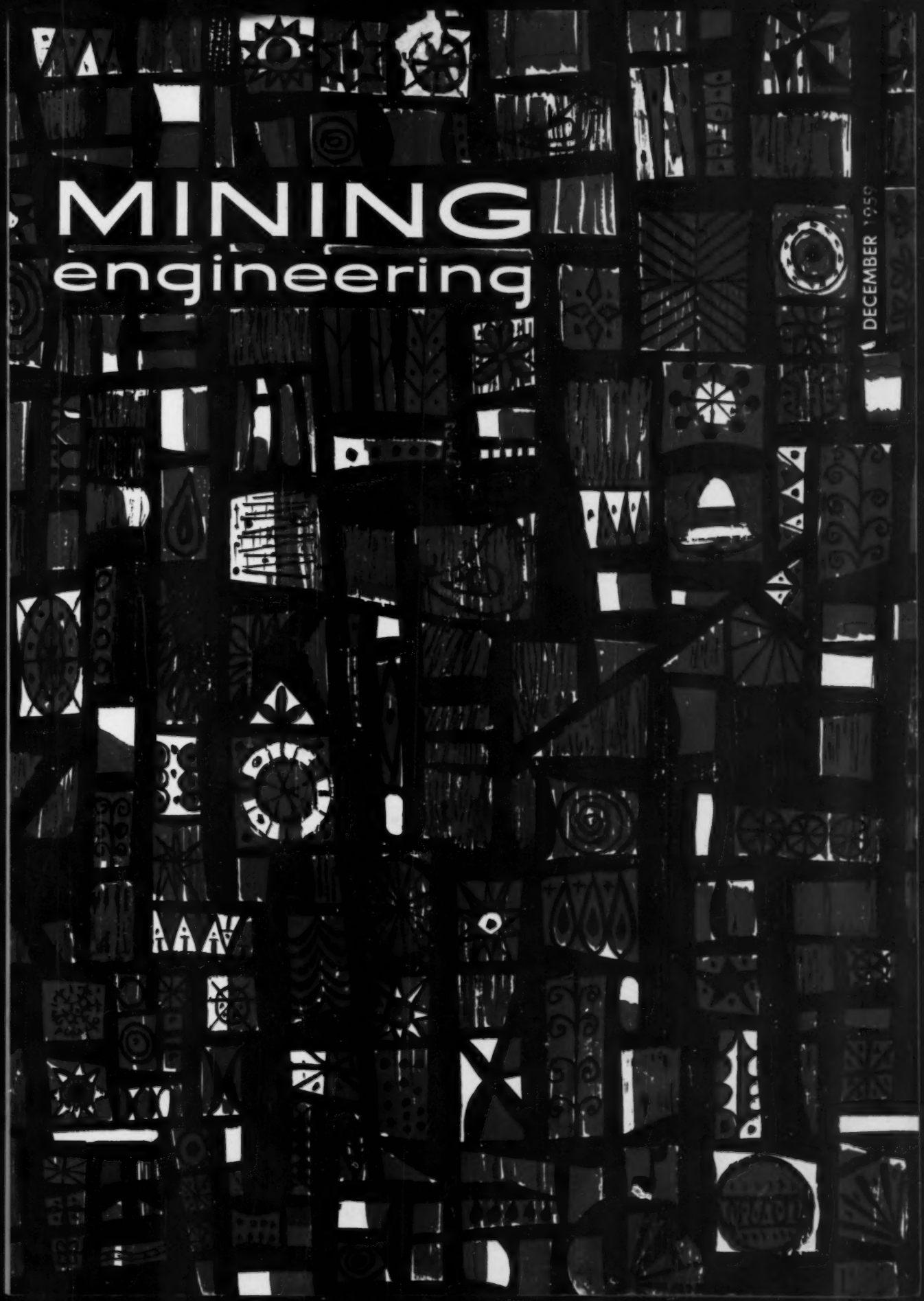
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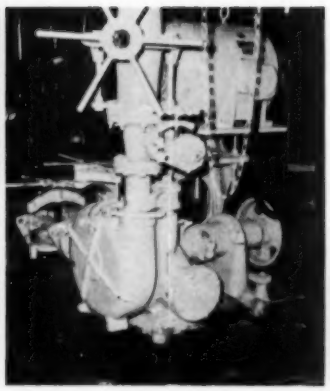

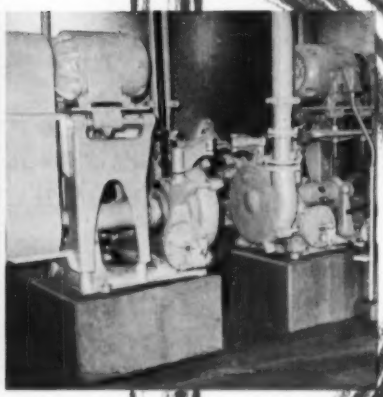

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Individual engineering on every application is standard practice with Wilfley. This personal attention to your specific requirements, plus Wilfley's day-in, day-out dependabilty, guarantee low cost pumping. Put a Wilfley Sand Pump to work . . . it will give you continuous, maintenance-free service, higher output, longer pump life, and quick, easy replacement of parts.

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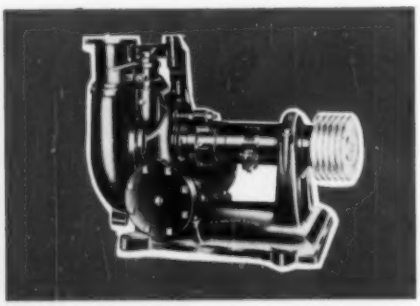

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COMING EVENTS

Dec. 17, AIME Utah Section, "A Geologist's View of the Montana Earthquake," by Dorsey Hager, Newhouse Hotel, Salt Lake City.

Jan. 6, 1960, AIME Chicago Section, "Nitrogen Quench of Experimental Blast Furnace," by J. L. Bosley, Chicago.

Jan. 11, AIME Minnesota Section, annual meeting, J. L. Gillson, speaker; L. C. Michelon principal technical speaker on subject "Lake Superior Iron Ores and the American Economy;" Duluth.

Jan. 12-13, 21st Mining Symposium, University of Minnesota, "Lake Superior Iron Ores and the American Economy," Norshor Theater, Duluth.

Jan. 21, AIME Utah Section, "Bear Creek Mining Company's East Tintic, Utah, Lead-Zinc Development," by J. B. Bush and D. R. Cook, Newhouse Hotel, Salt Lake City.

Feb. 3, AIME Chicago Section, "Ferro-Alloys Production, Uses, and Trends" by E. R. Saunders, Chicago.

Feb. 6, AIME Utah Section, Annual Miners Revue, Newhouse Hotel, Salt Lake City.

Feb. 14-18, AIME Annual Meeting, Hotels Statler and Sheraton-Atlantic, New York.

Feb. 16-17, 10th annual California Statewide meeting, Governor's Industrial Safety Conference, Fairmont Hotel, San Francisco.

Feb. 16-19, Australasian Inst. of Mining and Metallurgy, Symposium on Hydrometallurgy, "Wet Processing of Minerals and Industrial Products," Adelaide, Australia.

Mar. 2, AIME Chicago Section, "New Progress in Conventional Metal Forming Technologies" by N. H. Polakowski, Chicago.

Apr. 3-8, 1960 Nuclear Congress, sponsored by EJC, New York Coliseum, New York.

Apr. 4-6, AIME Blast Furnace, Coke Oven, and Raw Materials and National Open Hearth Steel Conferences, Palmer House, Chicago.

Apr. 4-6, AIME National Open Hearth and Blast Furnace, Coke Oven, and Raw Materials Conferences, Palmer House, Chicago.

Apr. 6-9, International Mineral Processing Congress, sponsored by The Institution of Mining and Metallurgy, Church House, Westminster, London, England.

Apr. 21-22, AIME Pacific Southwest Regional Metals and Minerals Conference, Ambassador Hotel, Los Angeles.

Apr. 25-27, CIM Annual Meeting, Royal York Hotel, Toronto.

Apr. 28-30, AIME Pacific Northwest Regional Conference, Sheraton Hotel, Portland, Ore.

May 9-11, American Mining Congress, Coal Convention, Pittsburgh.

May 9-13, 2nd Southwestern Metal Exposition and Congress, ASM, State Fair Park, Dallas.

May 16-20, International Conference on Strata Control, sponsored by Charbonnages de France, Paris, France

July 11-18, 2nd World Conference on Earthquake Engineering, organized by Science Council of Japan in cooperation with Japan Soc. of Civil Engineers, Architectural Inst. of Japan, Seismological Soc. of Japan; Tokyo and Kyoto, Japan.

Aug. 15-25, International Geological Congress, Copenhagen, Denmark; for information, write Mineralogical-Geological Museum, University of Copenhagen, Oster Voldgade 7, Copenhagen K, Denmark.

Oct. 5-7, AIME Rocky Mountain Minerals Conference, Utah Section host, Newhouse Hotel, Salt Lake City.

Oct. 10-13, American Mining Congress, Mining Show (metal mining-industrial minerals convention, exposition), Convention Center, Las Vegas, Nev.

Nov. 7, AIME Pittsburgh Section, Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Feb. 19-23, 1961, AIME Annual Meeting, Chase and Park-Plaza Hotels, St. Louis.

Apr. 12-14, International Symposium on Agglomeration, sponsored by SME, SPE, and TMS of AIME, Hotel Sheraton, Philadelphia.

Sept. 17-20, Commemoration of the 50th Anniversary of Froth Flotation in the U.S.A., sponsored by AIME: Society of Mining Engineers' Mineral Beneficiation Division, Cosmopolitan Hotel, Denver.

MINING engineering

Vol. 11 NO. 12 **DECEMBER 1959**

COVER *Artist Herb McClure has created a montage in the spirit of stained glass windows as his holiday theme for MINING ENGINEERING's traditional Christmas cover. The staff joins him in extending Season's Greetings and Best Wishes for the coming New Year.*

SME ANNUAL MEETING PLANS

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1224 Council of Economics Abstracts
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1230 Mining & Exploration Division Abstracts

TECHNICAL ARTICLES

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1244 High-Intensity Magnetic Separation of Iron Ores • *O. E. Palasvirta*

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MINING ENGINEERING staff, Society of Mining Engineers, and AIME Officers are listed on the *Drift* page.

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PERSONNEL

THESE items are listings of the Engineering Societies Personnel Service Inc. This Service, which cooperates with the national societies of Chemical; Civil; Electrical; Mechanical; Mining, Metallurgical, Petroleum Engineers, is available to all engineers, members and nonmembers, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5 pct of the first year's salary of a nonmember, or 4 pct if a member. Also, that you will agree to sign our placement fee agreement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number. When making application for a position, include 8¢ in stamps for forwarding application to the employer and for returning when possible. A weekly bulletin of engineering positions open it available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.**

Assistant Superintendent in a well-established sulfide flotation plant located in Eastern United States. Should have a degree in metallurgical or chemical engineering, at least ten years experience in sulfide flotation research and operating, and recognized executive ability. Must be able to organize and supervise the development program for improving the process, in addition to the normal duties of an assistant plant superintendent. Submit complete record and expected salary to **Box 10-ME.**

MINE SUPERINTENDENT AND METALLURGIST

REQUIRED

For mineral sand mining operation to be located in New Jersey. Excellent opportunities offered for men with right qualifications.

Qualifications for Mine Superintendent:

Age 30 to 45. Graduate of University or School of Mines. At least eight years experience in open pit dragline operations where rigid control of mining path and depth was necessary. The last five years to have been in a senior supervisory capacity. Should be experienced in the use of heavy equipment, pumps, preparation and planning.

Qualifications for Metallurgist:

Age 30 to 45. Graduate of University or School of Mines with degree in metallurgy. Must be experienced in the concentration and separation of sand ilmenite ores using spirals and other wet gravity methods. Also high tension and magnetic separation of ilmenite and related minerals. Should be qualified to take over duties of mill superintendent when plant is in operation.

Applications from completely qualified men alone will be considered. Reply with complete details and salary desired to:

Manager, Mining Division
The Glidden Company
RD. #4, Box 150
Lakewood, New Jersey

MEN AVAILABLE

Chief Engineer, experienced open pit and underground mining, heavy construction, mine plant design, project and engineering. Speaks Spanish; age 44; E.M. Registered Professional Engineer; domestic or foreign. M-512.

Mining Engineer and Metallurgist, B.S. in mining engineering; age 49; 24 years experience operating medium-sized South American mines as mine superintendent, mill superintendent, manager. Broad experience in design, construction, operation and maintenance of concentrators; underground development and production; writing mine, metallurgical and engineering reports. Fluent Spanish. Location immaterial. M-1008-Chicago.

Junior Geologist, B.S. (geology), age 23; two years in U.S. Army, 13 months asphalt and concrete testing; eight months Washington, D.C., Beach Erosion Board, Corps of Engineers, terrain analyst. Location, Wisconsin, Midwest, West or Northwest. M-1012-Chicago.

Mine Superintendent: B.S. EM, age 39. Experienced in underground mine layout, production, design and construction of surface plant. Shaft experience covering timbered, circular concrete and frozen shafts and also shaft grouting. Registered in Utah. Prefers western U.S. or foreign. S(M)-206.

Mining Engineer or Superintendent: age 55. Thirty-three years experience in mine survey and development, in charge of underground and open pit operations. Registered professional mining engineer. U.S. or foreign. S(M)-1237.

Mining Superintendent or Manager: B.S. in geological engineering, age 34. Three years experience in open pit mine, from planning to production, including exploration. Knows production, labor and equipment, strong in personnel. $700. Prefers western U.S. or foreign. S(M)-1227.

Mine Superintendent: B.S. EM, age 42. Six years experience in direction of operations, exploration, construction for coal, uranium base metals mining companies. $10,000. Any location. S(M)-1175.

Superintendent of Mining, Tunnels: B.S. EM, age 25. Two and one half years experience on research, development and construction of ice tunnel and arctic research for government. Also experienced as junior mining engineer in uranium and examination of mining properties. $6000. Any location. S(M)-1085.

Manager or Administrative Assistant: B.S. EM, age 46. Sixteen years diverse mining experience for large and small organizations. In supervisory capacity for five years in engineering and seven years operational and administrative work. Exceptional experience in mineral exploration, development, planning, construction, cost estimating for underground and open pit. Prefer western U.S. S(M)-1083.

Superintendent or Manager: B.S. EM (Canada), age 45. Over twenty years experience in metal mining operation and management. Experience in development, production, engineering planning and design. Desires position with good long term prospects. $800 to $1000 per month. Prefer Canada. S(M)-879.

Superintendent or Manager: B.S. EM, age 46. Twenty years progressive experience, mucker to mine superintendent, on exploration, development, production, heavy equipment application and maintenance, industrial relations and hardrock, zinc-lead, copper, limestone, and iron ore. Five years military administration and training. Process specialist. Prefer West, Midwest, Southwest. S(M)-524.

Mine Superintendent or Purchasing: B.S. in mining engineering, age 50. Thirteen and one half years experience as consulting engineer on manganese and copper mining. Also one and one half years experience in pro-

(Continued on page 1188)

URANIUM-VANADIUM MILLING POSITIONS

Mechanical, Chemical and Extractive Metallurgical Engineers and Chemists with good qualifications and 0 to 6 years of experience to work in Colorado Operations. Locations: Rifle and Uravan. Send resume and copy of college transcript to:

Union Carbide Nuclear Company
Division of Union Carbide Corporation
Post Office Box 1049
Grand Junction, Colorado

SENIOR RESEARCH ENGINEER

American-Standard has an opening at its Louisville Research Laboratory for a Senior Research Engineer.

Position requires definite interest in original research and the qualifications necessary to plan, execute and complete research and development projects of major scope with a minimum of supervision. Minimum requirements include an advanced degree in chemical engineering or metallurgy and six years of combined experience and/or graduate work in a position of responsibility dealing with major projects involving materials and processing development. Experience in ceramics desirable but not necessary.

Interested candidates please submit in confidence a detailed resume including salary requirements to Assistant Director of Research.

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PLUMBING & HEATING DIVISION

Research Dept., 834 East Broadway, Louisville 4, Kentucky

Walker Cut Stone Co., Milford, Kansas, replaced six smaller overworked gasoline haulers with only two 19-ton Model 65 Payhauler trucks! Their "65's" deliver 150 tons of limestone per hour, from quarry to crusher.

How new rock-ribbed 65 Payhauler® pair

speeds "write-off," replacing six smaller rigs!

—for Walker Cut Stone Co., Milford, Kansas

Two new International 19-ton 65 Payhauler trucks —with the new weight-saving corrugated bodies, and the new 250-hp D-817 diesel engine—have replaced six smaller gasoline trucks for Walker Cut Stone Co., Milford, Kansas.

Results are amazing! Only two operators instead of six to pay! Only 40 gallons of low-cost diesel fuel used daily (total) by the two Payhauler rigs—against several times 40 gallons of high-priced gasoline formerly swilled by the carbureted outfits! And only two machines to maintain, instead of six! "Write-off" of the Payhauler investment speeds in "high gear!"

Payhauler features increase capacity!

Even against competitive haulers of similar rated capacity, the new 65 Payhauler gives you overwhelming advantages!

Of all off-road haulers in its size class, only the 65 Payhauler has the International-developed rock-ribbed corrugated body! This strength-multiplying principle lets the "65" shed 5,000 lbs. of power-wasting weight, and gain a full ton of payload capacity.

Prove the power-to-payload advantages the new rock-ribbed 65 Payhauler delivers! Compare the "65's" cycle-speeding combination of air-assist shifting; 11-second dumping, fast reversing; super-power braking; bonus-leverage, vibration-free power steering! And for 27-ton capacity, note how the 375-hp "95" leads the field. See your International Construction Equipment Distributor for a demonstration!

In only 11 seconds you dump the "65's" 19-ton load —with 3-stage, double-acting, constant-power hoist! Positive up-and-down snubbing guards against impact!

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A COMPLETE POWER PACKAGE: Crawler and Wheel Tractors . . . Self-Propelled Scrapers and Bottom-Dump Wagons . . . Crawler and Rubber-Tired Loaders . . . Off-Highway Haulers . . . Diesel and Carbureted Engines . . . Motor Trucks . . . Farm Tractors and Equipment.

PERSONNEL

Continued from page 1186

curement, handling explosives and fuels, production control, supervising expeditors and liaison on missiles. Any location. S(M)-1003.

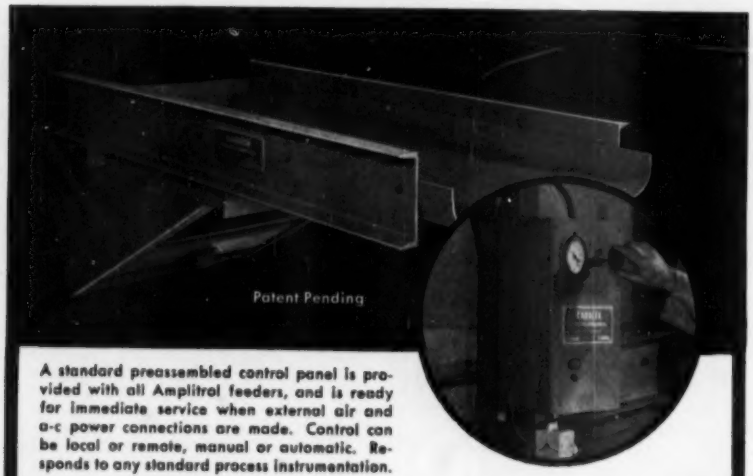
Geologist: M.S. in geology, age 25. Three years experience as geologist, traversing, air photo interpretation, sampling, stratigraphic correlation research, data processing, supervising field party for government. $6600. Any location. S(M)-977.

Mining Engineer or Geologist. B.S. in geology, age 31. Four years experience in mining geology and engineering; two years practical experience. At present, shift boss. Capable of mine survey, developing, planning, construction design, supervision and general mine work. $500 to $600. Prefer southwest U.S. or Latin America. S(M)-950.

Mining Engineer: B.S. in mining engineering, age 29. Experienced in field exploration, drilling, market research, mining leases, ore estimates, reports and underground mining. $6000. Prefer West or Foreign. S(M)-857.

Sales or Mining Operations: B.S. in mining engineering and metallurgy, age 45. Extensive experience in field work, lab and design, operation of flotation, gravity, chemical plants, sales engineering and management. $800 up. Prefer West or Foreign. S(M)-802.

Consultant or Instructor: M.S. in mining engineering, age 61. Continuous service in leading underground metal mines as engineer, superintendent, administrator of large and medium tonnage production with development, exploration and construction. Vice president and general manager of successful operation for past ten years. Salary open. Prefer U.S. S(M)-692.



A standard preassembled control panel is provided with all Amplitrol feeders, and is ready for immediate service when external air and a-c power connections are made. Control can be local or remote, manual or automatic. Responds to any standard process instrumentation.

Now! A Mechanical Vibrating Feeder With Variable, Stepless Control

The exclusive Carrier Natural-Frequency drive, and a unique new amplitude control system — these two features of the new Carrier Amplitrol feeder give you benefits found in *no other vibrating feeder*, electromagnetic or mechanical.

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FULL-RANGE CONTROL . . . A new, highly simplified pneumatic system allows accurate, full-range stroke control. The heavy-duty air springs respond *immediately* to a pneumatic signal from a standard 0-80 psi air pressure valve. No lag.

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POSITIONS OPEN

Plant Engineer, with mechanical, civil or mining engineering training and at least three years equipment operation, maintenance and installation experience at mining or quarry property. Salary open. Must be willing to relocate where assigned. Location, South. W8072.

Technical Graduate, mining or metallurgical, for test work in copper smelter. Salary open. Location, Southwest. W8065.

Recent Graduate Engineers, either mining or civil, with courses in geology, for prospecting and exploration relating to industrial minerals. Substantial portion of time to be spent in the field. Location, South. W8037.

Senior Engineers. (a) **Senior Electrical Engineer,** graduate, with about 15 years experience in the mining and milling field, for the design and layout of power distribution systems, for supplying power to crushers, rod mills, ball mills, conveying systems and allied equipment. Plant lighting system also included. (b) **Senior Structural Engineer,** graduate civil, with about 10 years experience in the mining and milling field, for the design of reinforced concrete foundations for large gyratory crushers, cone crushers, rod mills and ball mills. Also design of ore storage bins, mine and mill buildings, conveyor supports and galleries; also layout and design of mill and domestic water supplies and large tailings disposal systems. (c) **Senior Material Handling Engineer,** graduate mechanical, with about 15 years experience in the design of belt conveyors, screening, crushing and dust collecting installations, specifically in handling run-of-mine ore and crushed ore in modern high speed and large tonnage applications. Some operating experience valuable. Will be responsible for design of materials handling equipment as indicated above and with particular reference to the calculation of belt speeds and tresses, design of drives, takeups and dust control facilities. Salary to $14,000 a year. Location, New York, N.Y. W8001.

Assistant Mine Superintendent, 30-45, with underground hard rock experience to assist in supervision of all underground operations under direction of mine superintendent. Permanent. Salary about $7000 year to start. Location, South. W7868.

Mining Engineer: graduate, young, single preferred. Knowledge of geology with background in mining and metallurgy. Willing to travel extensively. Spanish helpful. $475-525. Texas headquarters. S(P)-4778.

Construction Engineer: Graduate civil engineering or mining engineering, young, several years heavy construction field experience involving civil or mechanical installation (foundations for buildings or equipment, general heavy mill type building). Should have supervisory experience and be able to carry out field layouts, surveys and deal with contractor and subcontractors. For a gypsum mine, board plant, and plaster mill. To $700. Nevada. S(P)-4774-R.

Metallurgist: Graduate in chemical engineering or metallurgy, under 30. Experienced in or having aptitude for lead smelting for development, research, and operation. $500 or more. Middlewest. S(P)-4785-R.

Surveyor and Mapper of Mine Properties: Graduate civil engineering or mining engineering, young. Good field survey experience in rough and rugged countries, able to translate field data into topographic and do mapping of lode claims and property layouts. Will conduct other office work relating to lode and claim. $550 to $600 per month. Location, Neveda. S(P)-4603.

Processing and Selling. Understudy for plant or management in nonmetallic minerals company, mining or buying non-metals for process and selling in Central California. Start in mining, training to do labor jobs, advance to production and finally into commercial aspects. Prefer to fill the need with professionally trained man. About $450 to start. San Francisco location. S(P)-4713.

Fabrication Research Engineers: B.S., M.S., or Ph.D. in metallurgical engineering or mechanical engineering. Minimum six years experience in metal processing (press working, spinning, machining, chemical milling, etc.) high strength steels, titanium and refractories. Some experience in research and development of metal fabrication processes and techniques desirable. $9000 to $15,000. Location northern California. S(P)-4690a.

(Continued on page 1193)

metal mining modernization

Savings by the second

Adjusting for wear is a one-man, one-minute operation on Superior crushers

Even on the largest *Superior* crushers, the time it takes to change settings is measured with a stop watch — not a calendar. The secret is *Hydroset* control. Flip a switch, it's that easy. Remarkable *Hydroset* control also facilitates emergency unloading. Remember, only Allis-Chalmers gyratory crushers offer this profit-building speed and convenience.

Bulletin 07B7870 tells the complete *Superior* crusher story. Get a copy from your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin. In Canada, write Canadian Allis-Chalmers Ltd., Box 37, Montreal, Quebec.

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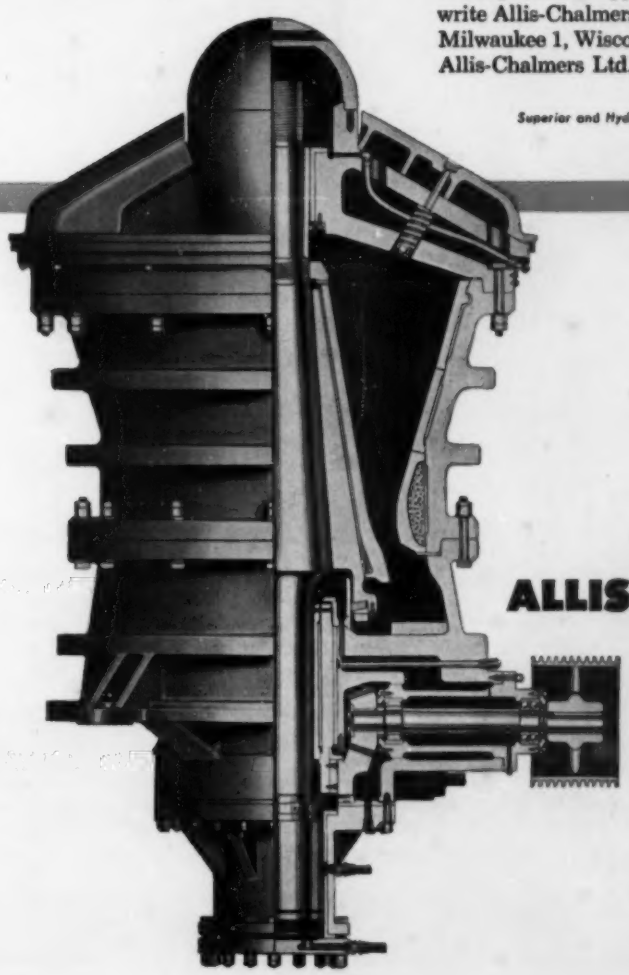

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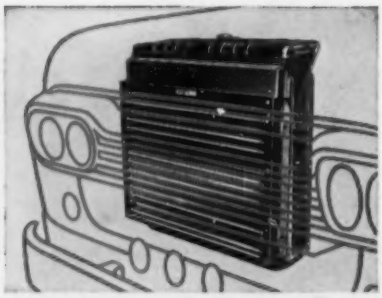
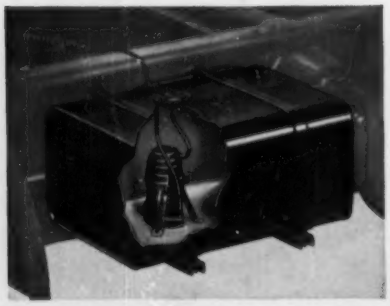


CLOSER TEMPERATURE CONTROL obtained with automatic radiator shutters means longer engine life, more efficient operation. Temperature variation between 167° and 187° with shutters as compared to 102° to 181° without shutters was reported and certified in loaded vehicle road tests.

LONGER WIRING HARNESS LIFE is the direct result of Ford's greatly improved electrical wiring system for 1960. Ford's '60 wiring harness and the 1959 wiring harness were subjected to shaker table tests plus constant exposure to oil and water vapors, and temperatures of 200°. Certified test results show a threefold increase in 1960 wiring harness life.



INCREASED FUEL PUMP RELIABILITY is an added benefit from Ford's submerged-type electric fuel pump. Certified results of dynamometer tests showed no vapor lock with Ford's electric pumps at temperatures up to 200°, whereas incipient vapor lock with mechanical fuel pump resulted in a power loss of 9% under same conditions.

It's a fact! Numerous reports from high-mileage operators of Super Duty Trucks attest to Ford's outstanding durability. Studies by an independent research firm provide certified proof that these models are even more durable for 1960.

Ford Super Duty Trucks have earned a reputation for exceptional performance and durability since their introduction two years ago. Shop service records of many leading fleets show Super Duty tractors with mileage readings between 150,000 and 250,000 and no repairs other than normal maintenance. Similar testimony to the dependability of these Big V's by other satisfied users is being added each month. Is it any wonder that '59 sales of these units were more than double those of 1958?

And for 1960, the Ford Super Duties offer additional refinements. Bigger optional axles and increased GVW's to permit greater payloads and more profitable operation. Automatic radiator shutters to keep the engine temperatures within the most efficient operating range, improved submerged-type electric fuel pumps to prevent vapor lock, and redesigned wiring for more reliable operation are typical of the improvements to be found in these units.

The changes offered for 1960 were tested and evaluated by a leading research organization. Certified results of the studies by this impartial firm (name available on request) provide proof that Ford's Super Duty Trucks are even more dependable.

- **Certified Durability through closer temperature control!** Independent research engineers certify that Ford's thermostatically controlled radiator shutters kept water temperature between 167° and 187° in severe mountain grade operation. The test truck with shutters blocked open under same operating conditions had a temperature range from 102° to 181°. The temperature variation of only 20° with shutters means less expansion and contraction in block and heads. Higher, more constant temperatures permit oil to circulate more freely, reducing internal friction. All these factors contribute to longer engine life.

- **Certified Reliability with longer-lived electrical system!** Thicker insulation on wires resists deterioration by heat, oil and gasoline. Asphalt-impregnated loom and plastic-coated mounting clips protect against abrasion. Certified results prove that the 1960 wiring harness has three times longer life.

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Endurance tests were run on alternators, two-speed axle speedometer adapters and other related components with similar results. Get all the facts at your Ford Dealer's now!

in Ford Super Duties!

"Our first Ford C-1000 tractor has logged 190,000 trouble-free miles since March of '58,"

says Robey W. Estes, Vice President and General Manager of Estes Express Lines, Richmond, Va. "We haven't had a single road failure and we only bring it into the shop for regular preventive maintenance work once a month.

"We use the 477 engine and find oil consumption is exceedingly low . . . only one or two quarts added between 3000-mile oil changes. Engine compression at 190,000 miles is still high and fairly equal and our drivers say that power and pep are at about the same level as when the truck had been run only 60,000 miles.

"We are grossing between 52 and 56,800 pounds with our Ford Tilts. They are giving about the same gas economy and better oil mileage than other makes in our fleet. We bought our fourth Ford C-1000 tractor last month and hope to add more soon."

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Vocational and Professional Monographs: Engineering, No. 14, by Edward H. Robie, *Bellman Publishing Co.*, Cambridge 38, Mass., 36 pp,. $1, 1959—The prestige of the author, formerly Secretary Emeritus of AIME and presently well known editor of engineering volumes, attests to the merit of this pamphlet which is directed primarily at high school students, their parents and vocational counselors. The booklet presents a concise history and definition of engineering along with information on professional activities, types of work in the field, qualifications, education, and training necessary for a young engineer.

Asbestos: Its Industrial Applications, by D. V. Rosate, *Reinhold Publishing Corp.*, 430 Park Ave., New York 22, N. Y., 214 pp., $5.75, 1959—The use of asbestos in industry is described, and data are given on its properties and manufacturing methods. The types of asbestos materials available are reviewed, including asbestos cement, tile, asbestos heat and electrical insulation, etc. • • •

Streckenausbau in Stahl, by Fritz Spruth, *Verlag Glückauf* GMBH, Essen, Germany, second edition, 256 pp, approx. $4.75 (20 DM), 1959—A practical comprehensive treatment of steel timbering in mines. A discussion of rock pressures precedes the description of the types and methods of framing applicable to various rock conditions and formations. Bolting and other special aspects are fully covered. • • •

Industrial Accident Prevention, by H. W. Heinrich, *McGraw-Hill Book Co., Inc.*, 480 pp., $9, 1959—The various ideas of industrial safety are discussed, from the basis and philosophy of accident prevention to specific details on planning and executing a safety program to fit any size and type of operation. • • •

Continuous Analysis of Chemical Process Systems, by Sidney Siggia, *John Wiley & Sons Inc.*, 381 pp., $3, 1959—Details are presented on new analytical devices that function automatically and directly in the processing equipment or pipeline, and which provide accurate and continuous monitoring of chemical process systems. • • •

Chemical Engineering Economics, by Chaplin Tyler and C. H. Winter, Jr., *McGraw-Hill Book Co.*, fourth edition, 187 pp., $7, 1959—The problems of investment, cost, price, and profit are analyzed in relation to chemical engineering projects. Means for resolving these problems are indicated, and realistic examples, based on current operating practice, are given as examples. • • •

Building Construction Estimating, by George H. Cooper, *McGraw-Hill Book Co. Inc.*, 398 pp., $5.50, 1959—The nature of the work of the estimator is covered in detail, and the various phases of contracting are discussed. The book begins by discussing contracting as a business, building codes, plans, specifications, contracts, and general techniques of estimating. • • •

Automation, Cybernetics, and Society, by F. M. George, *Philosophical Library Inc.*, 15 East 40th Street, New York 16, N. Y., $12, 1959—An attempt to clarify the overall picture of automation and its ramifications. The author begins with the distinction between non automatic and automatic control of new and complicated pieces of machinery, and then continues with an examination of the nature of science, and of automation. • • •

Chemical Engineering Calculations, by Ernest J. Henley and Herman Bieber, *McGraw-Hill Book Co. Inc.*, 441 pp., $9, 1959—A text which provides a comprehensive treatment of "first law" thermodynamics and phase diagrams as well as an exposition of material-balance calculations. • • •

New Instruments and Methods of Engineering Geology, by N. V. Galzov and A. N. Galzov, *Consultants Bureau Inc.*, 227 West 17th St., New York 11, N. Y., 91 pp., $3.25, 1959—In this translation from the Russian a concise review is given of new methods and apparatus which can be applied in improving the quality and productivity of exploratory work in engineering geology and hydrogeology. • • •

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ABSTRACTS

In This Issue: *The following abstracts of papers in this issue are reproduced for the convenience of members who wish to maintain a reference card file and for the use of librarians and abstracting services. At the end of each abstract is given the proper permanent reference to the paper for bibliography purposes.*

Quantitative Mineralogy as a Guide in Exploration by *R. J. P. Lyon* and *W. M. Tuddenham* (TP 59177)—At Kennecott's Research Center all samples received are now processed with infrared spectrophometer, X-ray diffraction, and differential thermal analysis units on a routine basis. These semi-automatic instruments are unaffected by grain size of the minerals and greatly assist rapid quantitative determinations. When coupled with thin-section and polished-section study of the rocks,this integrated approach gives better overall coverage, combining the areas of mineralogy in which each particular instrument is most sensitive. **Ref.: (MINING ENGINEERING, December 1959) AIME Trans., 1959, vol. 214, p. 1233.**

Retention Time in Continuous Vibratory Ball Milling by *D. W. Fuerstenau* (TP 60B10)—The variable s hypothesis of Charles and Holmes can be extended to continuous grinding through the use of retention time as a measure of the energy expended on a material during comminution. This was verified experimentally by grinding chromite in a continuous, open-circuit vibratory ball mill. For continuous grinding, a statement of the grindability of an ore must include a factor which determines the fraction of the total energy which is being utilized for grinding. This factor depends upon the weight of material retained in the mill at steady state. **Ref.: (MINING ENGINEERING, December 1959) AIME Trans., 1959, vol. 214, p. 1238.**

High-Intensity Magnetic Separation of Iron Ores by *Osni E. Palasvirta* (TP 59B73)—On the basis of theoretical considerations and laboratory studies, an ideal high-intensity, induced-rotor magnetic separator is described. Selected test data, obtained with a less than ideal laboratory separator, indicate that certain ores of simple mineralogy respond favorably to high-intensity magnetic separation but that others of seemingly simple mineralogy do not. Commercially available separators are reviewed in the light of the principles found valid in the present investigation. **Ref.: (MINING ENGINEERING, December 1959) AIME Trans., 1959, vol. 214, p. 1244.**

SME Meeting Papers: *The following abstracts of papers presented at SME meetings are given for your information. Copies of these papers are available* **only if followed by a preprint order number.** *These preprints are obtained on a coupon basis. The coupon books may be purchased from SME headquarters for $5.00 a book (10 coupons) for members of AIME or $10.00 a book for nonmembers. Each coupon, properly filled out, entitles the purchaser to one preprint. Mail completed coupons to Preprints, Society of Mining Engineers, 29 W. 39th St., New York 18, N. Y.*

Electrode Effects in Streaming Potential Measurements by *N. Arbiter* and *G. Zucker*—Streaming potential measurements are subject to an important source of error, an error which may exceed the magnitude of the true streaming potential. A potential difference can arise when the cell electrodes alone undergo motion with respect to the electrolyte and are associated with the polarizability of the electrode materials. A reversible electrode in a flow system measured against an electrode in a quiescent compartment has its potential changed by electrolyte flow; but two electrodes identical in geometry as well as in reversible e.m.f. exhibit no potential differences upon flow of electrolyte.

Streaming potential literature is scrutinized with respect to the interpretation placed upon zeta potential measurements and with respect to the validity of the data taking into consideration the electrode flow potentials. Measurements with proven reversible electrodes are made on the minerals barite and quartz. The results on barite differ from previously recorded zeta potential data, but factors other than electrode flow potentials may be involved. The results with quartz differ significantly from those of other investigators indicating that interpretations drawn from the earlier results are invalid. *Joint SME Meeting, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Electrophoretic Mobility and Charge Distribution in $BaSO_4$ Suspensions by *R. H. Smellie, Jr., M. H. Forbes,* and *V. K. LaMer*—The electrophoretic mobilities of particles of finely-ground $BaSO_4$ suspended in water have been measured using a micro cell. In freshly prepared suspensions (in the absence of added electrolyte), both positively and negatively charged particles are present and the charge distribution is broad. During a period of 30 minutes to 1 hour after preparation, the electrophoretic velocities of individual particles change rapidly and a considerable narrowing of the charge distribution is observed. All the particles which were originally positive finally acquired a negative charge. In order to study the initially very wide distribution in the charge of suspended particles, a technique which would permit measurements on a large number of individual particles simultaneously was necessary. The relatively rapid variation of the charge distribution made it virtually impossible to measure the electrophoretic velocities of a sufficiently large number of different particles (by the separate visual observation of single particles) to give a quantitative indication of the charge distribution at any given time. The possibilities of a photomicrographic method for measuring the electrophoretic velocitites and the sign of the charge on a number of particles simultaneously have been investigated.

The electrophoretic mobilities are quite sensitive to the addition of very small amounts of barium chloride and sodium sulfate. The experimental results are discussed in respect to adsorption and to theory of electrophoresis. *Joint Meeting SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

Measurements of Heats of Wetting of Montmorillonites by *Eric Hutchinson* and *Douglas I. Longwell*—A semimicro calorimeter, which has been previously described, has been used to determine the heats of wetting in water of a number of carefully purified montmorillonites, in which the exchangeable cation varies from hydrogen to cesium. Earlier work has shown that the heating of wetting per gram of clay is independent of the particle size, owing to the characteristic expanding lattice structure of the montmorillonites. The heat effects associated with wetting can be clearly divided as follows: 1) hydration of the exchangeable cation; 2) wetting of the silicate surface lattice layers; 3) separation of the cations and charged planes. The third item has been shown to be small, by measurements of heats of dilution; the second item has been measured by studying the heat of wetting of pyrophillite—which has the same structure as the montmorillinites but has no exchangeable cations. Accordingly, by a combination of the various experimental results, it is possible to estimate the hydration energies of the exchangeable cations in the montmorillonites. *Joint Meeting SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

The Adsorption of Surface Active Anions and Their Gegenions to the Graphon/Solution Interface by *A. C. Zettlemoyer* and *J. D. Skewis*—Graphon, a graphitized carbon black, has been used as an adsorbent in aqueous solutions of sodium dodecylbenzene sulfonate and sodium lauryl sulfate. Adsorption isotherms of the surface-active anions and their associated gegenions have been measured by means of radioactive tracer techniques and surfactant titration methods. The surface-active anions are adsorbed preferentially to the Graphon substrate with the amount adsorbed attaining a constant value just above the critical micelle concentration (C. M. C.) of the surfactant solution. The calculated limiting areas per adsorbed surfactant anions are in reasonable agreement with values previously reported for the air/solution interface and demonstrate the interfacial film to be an ionized monolayer. Addition of sodium chloride or calcium chloride increases the adsorption of surface-active anions both above and below the C.M.C.

Sodium counterions are adsorbed in lesser amounts than the surface-active anions if the surfactant concentration is below the C.M.C. Above the C.M.C. or with the addition of sodium chloride, the adsorbed sodium counterions exceed the number of adsorbed surface active anions. With the addition of small amounts of calcium chloride to the solutions, the sodium ions are displaced from the interface by the subsequent adsorption of calcium ions. The limit of this calcium ion adsorption is in the ration of one calcium ion per two surface-active anions. Above the C.M.C. of the surfactant solutions, the calcium ion adsorption is decreased due to complexing between calcium ions and the micelles in solution. This is further substantiated by a sharp break at the C.M.C. in the solubility versus surfactant concentration curve for the calcium surfactant salts. The data indicate the sodium ions to be adsorbed as a diffuse counterion layer. In contrast to this, the adsorbed calcium ions form the unionized surfactant salt with surface-active anions in the interface. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

The Effect of the Spreading Solvent on the Properties of Monolayers by *V. K. LaMer* and *M. L. Robbins*—The molecular area of a stearic acid monolayer increases as the concentration of stearic acid in the benzene spreading solution is decreased. Also, the molecular area is independent of the volume of solution delivered to the surface, the initial area of the surface, or the time allowed for benzene to evaporate. The formation of a mixed monolayer of stearic acid and benzene was proposed as a model to explain our observations. Later experiments have shown that monolayers of octadecanol spread from both benzene and hexane expand with more dilute spreading solutions in the solid as well as the liquid condensed region of the surface pressure-area curve. Similar expansions were observed when 1) droplets of benzene were added to the monolayer, 2) the monolayer was flushed with benzene vapor, 3) the concentration of benzene dissolved in the subphase was increased. These experiments were time dependent and showed an expansion of the monolayer with age. In all cases, the expansion with both age and added benzene was irreversible, i.e. no contraction was observed when the expanded monolayer was flushed with air. Since benzene was adsorbed but not desorbed, the initial presence of benzene in the surface from the spreading solution should result in some benzene being retained in the surface. *Joint Meeting, SME, MBD-American Chemical Society, Div. of Colloid Chemistry, Atlantic City, N. J., September 1959.*

PERSONNEL

Continued from page 1188

Welding Research Engineers: B.S., M.S., or Ph.D. in metallurgical or mechanical engineering. Minimum six years experience welding and/or brazing high strength steels and refractories. Some research and development of metal joining processes and techniques desirable. $9000 to $15,000 yearly. Location, northern California. S(P)-4690b.

Metallurgical Engineers: B.S., M.S., or Ph.D. in metallurgy or metallurgical engineering, metal processing or metal joining of high strength steels, titanium and refractories. $9000 to $15,000. Location, northern California. S(P)-4690c.

(a) **Designer,** mining, civil, or mechanical engineering degree preferred, with previous industrial design experience in connection with mining, ore dressing and smelting or refining plants, equipment, and facilities. $800 to $850. (c) **Estimator,** mining, metallurgical or mechanical engineering degree. Broad experience in heavy industrial construction and engineering estimates, preferably mining and mineral industries. Qualified to make cost estimates on projects budgetary and appropriation estimates, supervise small group. Salary and benefits. Western U.S. location. S(P)-4627.

Mining Engineer: B.S. in mining engineering, under 50. Experienced in underground and possibly some open pit mining process operating retor for murcury extraction. Should be abie to open mine operation and carry it through to production and mill operation and installing mill and retort equipment. $800 to $1000 per month, plus bonus. Location, High Sierras. S(P)-4611.

NEW CAT DW20 4-wheel, 345 HP Series G Tractor with 24 cu. yd. No. 482 Scraper

NEW CAT DW21 2-wheel, 345 HP Series G Tractor with 19.5 cu. yd. No. 470 Scraper

NEW CAT No. 619 2-wheel, 225 HP Series B Tractor with 14 cu. yd. No. 442 Scraper

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Matching the increased horsepower and productivity of the Series G Wheel Tractors are the new No. 456 and No. 470 Series B LOWBOWL Scrapers. Rating is increased 8% to 19.5 cu. yd. struck and 27 cu. yd. heaped. (Rating on the No. 482 is 24 cu. yd. struck and 34 cu. yd. heaped.) Bowl, draft frame and apron are strengthened for greater resistance to tough materials and rugged loading—withstand higher loading stresses.

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DW15 Series F Wheel Tractor and No. 428 LOWBOWL Scraper Greater strength and productivity in the well-known four-wheel DW15-No. 428. Bevel gear and pinion, differential and front wheel spindles offer increased service life. Machine delivers 200 HP. The big LOWBOWL Scraper handles 13 cu. yd. struck, 18 cu. yd. heaped. Can be unhitched to haul other units.

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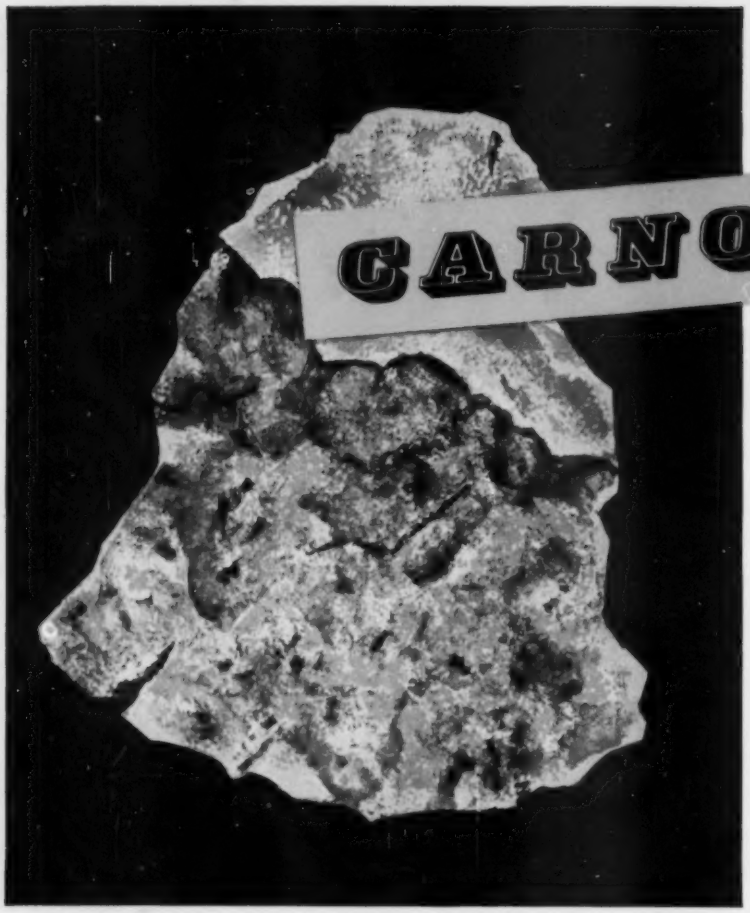

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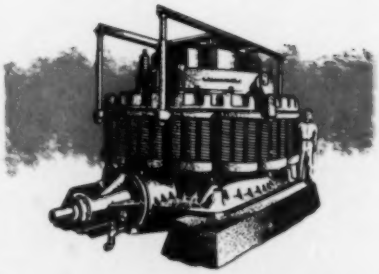

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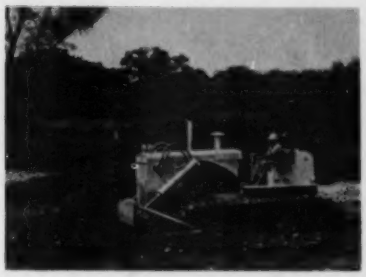
MANUFACTURERS NEWS

NEWS / EQUIPMENT / CATALOGS

Biggest I-H Crawler

International Harvester Co. has available its new TD-25 diesel crawler tractor—the biggest ever produced by the company. Equipped with either a torque converter or



gear drive, the crawler is equipped with a 6-cyl turbocharged engine that develops 230 net hp at the flywheel at 1500 rpm. Direct electric starting system is 24-v. **Circle No. 1.**

Jumbo Feed Mountings

New channel screw feed mountings for jumbo drilling operations have been introduced by *Gardner-Denver Co.* The 2MC series feeds mount 4½ and 5½-in. percussion drills. Automatic wet controls are standard, but they can easily be

converted for dry drilling. Power is supplied by a Gardner-Denver 5-cyl radial air motor. Its exhaust is used for self-lubricating. The three mounting models are offered with 10, 12, and 14-in. drill changes. **Circle No. 2.**

Tractor Shovel

Allis-Chalmers' Springfield Works is now turning out the new 1½-cu yd HD-6G tractor shovel. Dumping

height of the unit is over 9 ft, ample reach for most applications. Diesel engine is rated at 72 net hp. Four forward speeds, two reverse may be selected with a single lever shift. **Circle No. 3.**

Magnetic Separator

Designing to cut costs in beneficiation of most dry, granular iron ores, *Dings Magnetic Separator Co.* has developed a new high intensity, induced roll magnetic separator. The new type IR unit is available in widths from 2 to 30 in., with from one to seven rotors. **Circle No. 4.**

Dry Drilling

Dust collecting system introduced by *Le Roi Div.*, Westinghouse Air Brake Co., can be used with any brand of rock drill. Dust and cuttings are trapped by a collar that fits around the steel and taken

through a hose to a dust collecting tank. **Circle No. 5.**

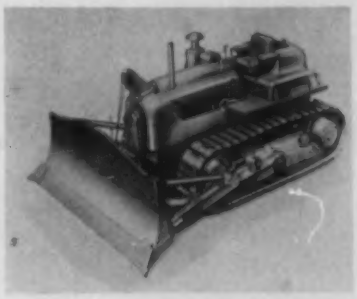
ITV

Motorola Inc. has introduced a line of five closed-circuit TV cameras and two monitors. Basic general purpose camera weighs 12 lb and measures 5½ x 7 x 11 in. Remote control functions can be added.

Monitors offer 14 and 21-in. screens. **Circle No. 6.**

Crawler Tractor

New design *Euclid* model C-6 tractor is in production after 5 years of testing and development. Torque converter and semi-automatic that eliminates master clutch provides three forward speed ranges and



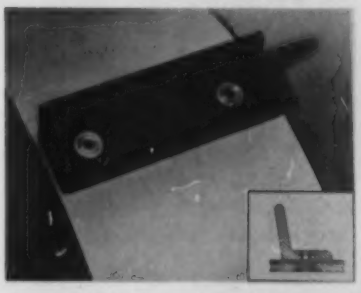
reverse. The 42,000-lb machine is rated at 211 net hp. **Circle No. 7.**

Cat D9 Series E

Designated the *Caterpillar* D9 series E, the new unit is available in choice of direct or torque converter drive, as well as power shift version. Addition of more efficient turbocharger raises rating to 335 hp. Dimensionally machine is close to predecessor. Prime improvements in the new D9 are concentrated in the undercarriage components. Matched equipment for the tractor unit is also announced. **Circle No. 8.**

Conveyor Cleats

Low cost rubber conveyor cleats for easy belt punch and screwdriver installation have been developed by *Holz Rubber Co.* Resilient construc-



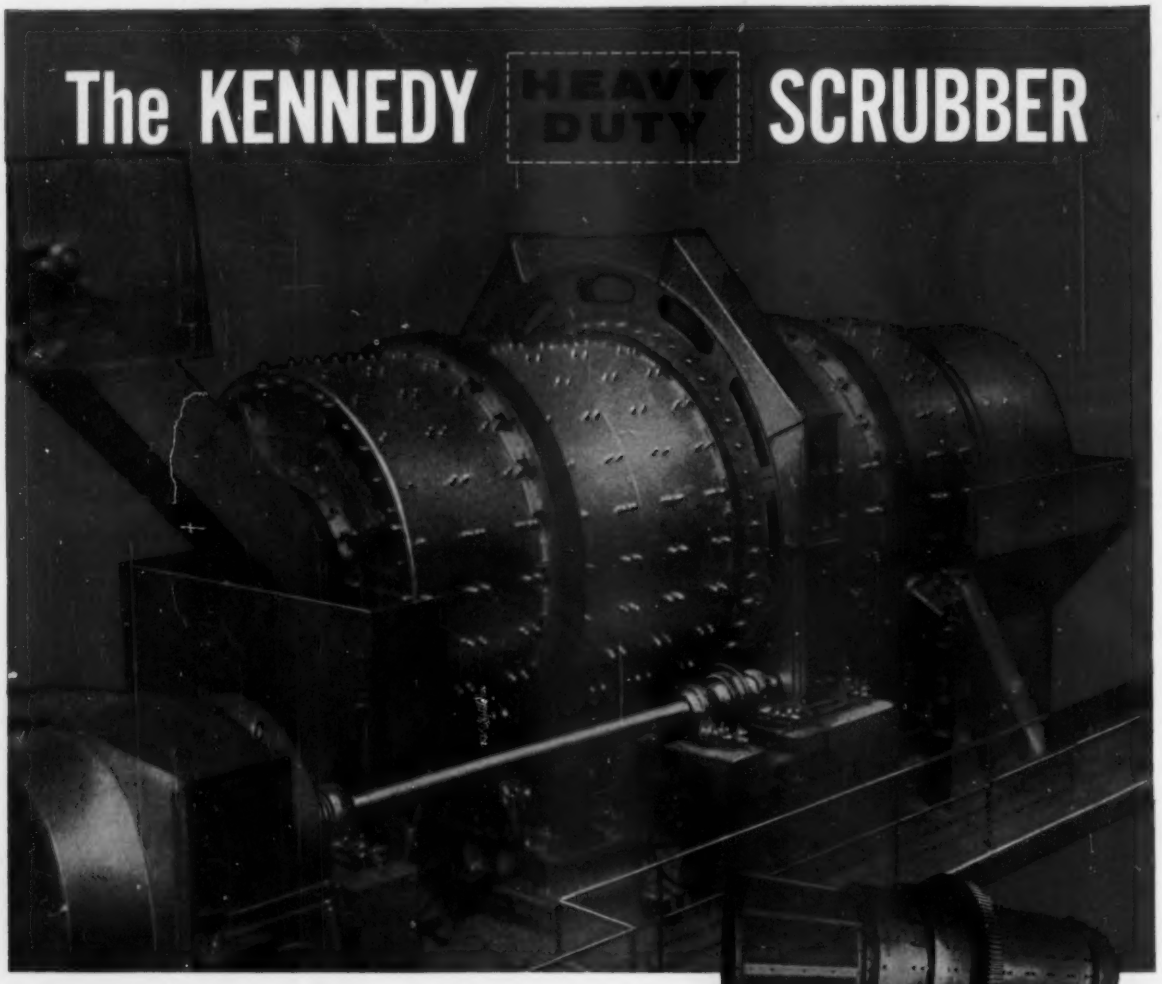
tion safeguards soft products and increases belt life. Metal stiffeners are available for heavy duty service. **Circle No. 9.**

Precision Fine Grind

Southwestern Engineering Co. is placing on the market the Vibro-Energy mill for both wet and dry ultra fine grinding. Unit applies high frequency vibration plus circular movement to a special type grinding media. Developed in England, mills are being built under a contract with W. Boulton Ltd. and W. Podmore & Sons Ltd., both of Stoke-on-Trent. **Circle No. 10.**

A Cleaner Product Is A More Saleable Product

The KENNEDY HEAVY DUTY SCRUBBER



With thoroughly cleaned rock or ore secondary and tertiary crushing and screening operations become more efficient. Control is improved and products are of higher quality. Downtime for blocked crushers or blinded screens is eliminated.

The KENNEDY Heavy Duty Scrubber is outstanding because of these features:

- **All welded steel shell**
- **Wear resistant, replaceable liners**
- **Replaceable cast alloy lifters for advancing material**
- **Spherical roller bearings**
- **Cut gear and pinion**
- **Enclosed gear reducer drive**
- **Extra heavy structural steel base**
- **Counter flow of material and wash water**
- **Single, double or multiple trommel for dewatering and sizing**

◆ *View showing rotary kiln type carrying stations with spherical roller bearing pillow blocks and extra heavy base.*

◆ *Discharge end of scrubber with double trommel. Dirt and clay wash through outer trommel; sized material discharges off end. Oversize discharges off end of inner trommel.*

Let us help you adapt this scrubber to your process.

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MANUFACTURING & ENGINEERING CORPORATION

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PRIMARY & SECONDARY GYRATORY CRUSHERS • JAW CRUSHERS • ROLL CRUSHERS • IMPACT BREAKERS • HAMMER MILLS • ROD & BALL MILLS • KILNS • KILN ACCESSORIES • DRYERS • SCREENS • MECHANICAL & PNEUMATIC CONVEYORS • COMPLETE CRUSHING, LIME, CEMENT & CARBON PASTE PLANTS. KENNEDY RESEARCH & TESTING SERVICE.

(21) INSTALLMENT SALES PROGRAMS: *Standard Financial Corp.* has published a brochure describing a new plan that will enable mining equipment manufacturers to set up full programs for installments sales of their income-producing equipment, obtain complete financing, and have the financing company handle all the customer credit, collection, and paper work at no extra cost.

(22) JAW CRUSHERS: Bulletin BR-5 illustrates jaw crushers built by *Gruendler Crusher & Pulverizer Co.* Design and construction are of finest, highest strength steel alloys for crushing power and continuous operation with a minimum of maintenance.

(23) TRACTORS: The rubber-tired Tournatractor from *Le Tourneau-Westinghouse Co.* is described in detail in 16-page bulletin TD-280. Cost-cutting features, speed, mobility, and versatility are the highlights of 218-hp model C.

(24) SCRAPER, DUMPER: *International Harvester Co.* model 495 Payscraper and Paywagon are outlined in 36-page catalog. Features include 34-cu-yd heaped and 24-yd struck capacities, 375-hp engine with 35.7-mph top speed, and an advanced lift frame design.

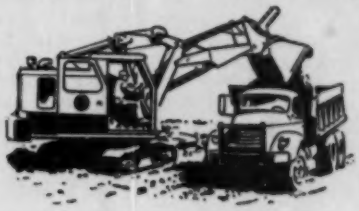
(25) AIR COMPRESSOR: *Ingersoll-Rand Co.* has published a booklet entitled "Compressed Air Fundamentals" to aid in selection of small, packaged air compressors for either automotive or industrial applications.

(26) COUNTERS: A complete line of heavy duty counters for indication, recording, and automatic regulation of material flow is described in 4-page bulletin 0159 issued by *Richardson Scale Co.* Models are designed for use with machinery all along the line of material flow, in receiving, process and inventory control, and shipping.

FREE LITERATURE

(27) DUMP TRAILERS: Unusual performance features and low maintenance costs provided by Galion tandem-axle, lightweight, 26-ft, 15-cu yd capacity frame type dump trailers are shown in a folder from *Galion Allsteel Body Co.* Outlined in detail are hauling, dumping, and stockpiling operations.

(28) LOADERS: The unique features of the model 205 Skooper, a full-revolving, crawler-mounted front-



end loader which can load up to 400 tph, are described in 2-color 8-page bulletin K-636 now available from the Koehring Div., *Koehring Co.*

(29) MOTOR: Submersible motors from *Louis Allis Co.* are designed to drive deep well turbine pumps in domestic and industrial water supply applications. Bulletin 3450 outlines motor capacities and specifications.

(30) TRACTOR-SHOVELS: *Allis-Chalmers Mfg. Co.* 3 and 4-cu yd tractor shovels with torque converter drive are featured in bulletin MS-1274. Photographs of the HD-16G and HG-21G models show operating, performance, and maintenance averages offered by the shovels.

(31) PROCESS EQUIPMENT: A catalog guide of equipment for the process industries has been released by *Allis-Chalmers Mfg. Co.* Included in the guide are descriptions of compressors, pumps, and valves for fluid flow; crushers and grinding and roller mills for disintegration, mixing, and agglomeration; screens for dry separation; mills, screens, and log washers for liquid separation; kilns, dryers, slakers, pelletizers, coolers, and liquid heaters for heat transfer. The guide also covers electrical equipment for the complete process plant, electronic metal detectors, water conditioning equipment, chemicals and service, as well as car shakers, lift trucks, tractors, etc. Ask for catalog 25C6177P.

(32) LOG WASHER: a new 6-page bulletin MM-90 on the McLanahan Mudmaster log washer has been published by *McLanahan & Stone Corp.* This bulletin includes construction and design information as well as a dimensional drawing and parts list.

(33) WELL DRILLING: New 12-page well drilling bulletin for water wells and shallow oil wells, form 4209, describes the highly mobile, over-the-highway Drillmaster unit, designed to utilize the I-R Downhole drill from *Ingersoll-Rand Co.* Detail procedures for water wells and shallow oil wells and typical cost analysis comparisons for both types of jobs are provided. Complete specifications included.

(34) EXTRACTOR: Folder T-1159 describes the Turbo-Mixer rotating disc contactor, a simply constructed, compartmented column using rotating discs. Used as an extractor for liquid-liquid, liquid-solid, or liquid-slurry operation, the extractor is a product of *General American Transportation Corp.*

(35) CRAWLER TRACTOR: Euclid Div. of *General Motors Corp.* has just released a 24-page brochure on the model C-6 crawler tractor. The trac-

mail this post card for more information

12

Mining Engineering 29 West 39th St. New York 18, N. Y.

Not good after March 15, 1960.

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

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61	62	63	64						

Students should write direct to manufacturer.

tor has had 5 years of exhaustive tests. This full-color booklet is well illustrated with photographs of job applications. Condensed specifications performance charts, as well as data on hydraulic and cable control attachments are included in form 607.

(36) HOISTING SYSTEMS: A new pamphlet on semi-automatic hoisting practices for small mines explains the use of a low cost hoisting system for nearly all possible hoist applications. Major savings in manpower are effected by the use of compact, economical skip-cages with integral push-button controls in an A.C. power system. Safety is another major advantage. Booklet HP-5911 from *Vulcan Iron Works Co.* outlines wide range of application.

(37) TRUCK CRANE: A 16-page catalog 770-TG-2 describing a 60-ton truck crane has been released by *American Hoist and Derrick Co.* Actual illustrations are shown from large engineering projects and big lifts. The catalog also describes exclusive features on the 60-ton capacity 700 series truck crane.

(38) BELT CONVEYOR: *Stephens-Adamson Mfg. Co.* has announced the release of bulletin 458 on new pre-engineered sectional belt conveyor. This literature features comprehensive technical data, pre-engineering advantages, and an exploded view of the conveyor with all the quality components called-out.

(39) SUPPORT SYSTEM: *Dowty Mining Equipment Ltd.*, has published a well-illustrated 8-page brochure on the Roofmaster, a fully mechanized support system for use in longwall coal mining. The Dowty Roofmaster will provide for all functions of roof control on a 600 ft longwall coal face with only two men. Production of 100 tons per man shift is made possible through longwall techniques and the use of a Roofmaster.

(40) CONVEYOR: The 56-page *Jeffrey Mfg. Co.* spiral conveyor book offers engineering data, conveyor layouts, capacity tables, conveyor selection and horsepower requirements. Sections devoted to couplings and shaftings, hangers, trough ends, unit drives, throust bearings, and accessories round out the comprehensive information presented. Conveyor specification is detailed and tables and photos supplement the exposition.

(41) VALVES: WKM Div. of *ACF Industries Inc.* has data on a new line of pressure-sealing steel gate valves that provide a tight seal both upstream and downstream and require no lubrication. The range of sizes from 2 to 30 in. is designed for a variety of uses in mining such as control on slurry lines, including lines used in hydraulic dredging and mining.

(42) PAYSCRAPER: The new *International Harvester Co.* model 295 Payscraper is the subject of a 24-page, 2-color catalog just released. With a 34-yd heaped capacity, the unit is powered by DT-817 turbocharged engine, developing 375 hp at 2100 rpm.

(43) MOTORIZED WHEEL: Information on performance of *General Electric Co.'s* new motorized wheel for off-highway mining and excavation vehicles and how it can cut haulage costs is contained in bulletin GEA-6931. This 4-color publication illustrates application, operation and bonus benefits which eliminate the need for axles, transmission, differentials, and drive shafts.

(44) CRUSHER: Mechanical features of the 36-in. Hydracone crusher are described in bulletin 17B9296 released by *Allis-Chalmers Mfg. Co.* Available with instantaneous hydraulic adjustment for wear and product size, the crusher can be had with fine, intermediate or coarse crushing chambers. Affording big machine advantages, the crusher is only 4 ft 10 in. high.

(45) WEIGHING SYSTEMS: The automatic measurement and control of bulk materials through unitized weighing systems of pre-engineered components is the subject of a new bulletin issued by *Weighing & Control Components Inc.* The bulletin (number 14) explains the application of the company's standardized system of instrumentation to batch and continuous weighing methods.

(46) RECTIFIER: Six-page bulletin GEA 6977 describes *General Electric Co.'s* Lo Boy portable silicon rectifier. Cars are mounted on wheels for use on rails, and have no moving parts except for fans.

(47) SHOVEL REPLACEMENT PARTS: The Kensington Steel Div. of *Poor & Co.* has released a new 2-color, 4-page brochure on a line of shovel replacement parts. Many illustrations show the versatility and construction of a complete line of long wearing parts for all makes and models of crawlers, shovels, cranes, and draglines. Ask for bulletin 1060.

(48) RESCUE EQUIPMENT: Complete details on *M-S-A* Porto-Power hydraulic rescue equipment are provided in bulletin 0911-1 now available from *Mine Safety Appliances Co.* Three packaged Porto-Power sets are described, covering operating principles of the equipment, which combines a hand-powered hydraulic pump and hydraulic ram to convert manual power into a maximum of 20 tons of power applied to rescue operations.

(49) FATTY ACIDS: A revised 34-page edition of "The Chemistry of Fatty Acids" has been prepared by the *Armour Industrial Chemical Co.* Preparation, characteristics and application of Armour's 30 fatty acids, trademarked Neo-Fat, are detailed and specifications, sources and composition of fatty acids, saturated and unsaturated types are also covered.

(50) TIRES: Complete data on new U. S. Royal Con-trak-tor tires are available in bulletin T5925 from *U. S. Rubber Co.* The steel reinforced tread is 50 pct deeper and the nylon gives double strength. Tests over seven years of development are described.

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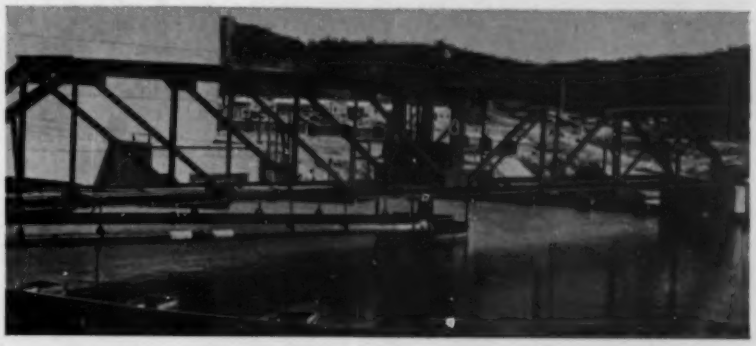
EIMCO *design and production*
PROGRESS REPORT
B-405
Process Engineers, Inc., Division of The Eimco Corporation: 420 Peninsular Ave., San Mateo, Calif.

Operating Flexibility Provided By Eimco-Process Thickeners At Canadian Uranium Mill

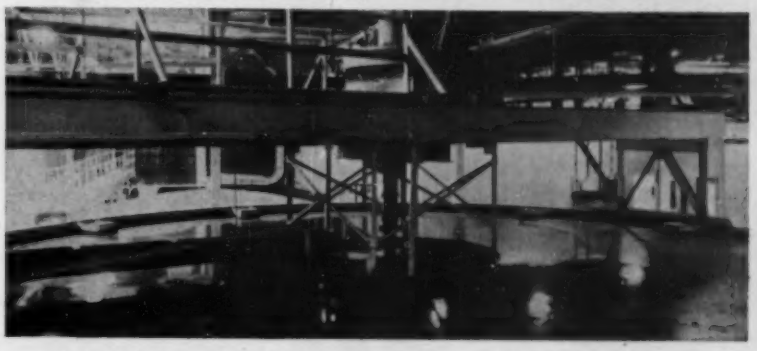
Lifting devices that can raise or lower the entire mechanisms as much as 12 inches while they are running are features of two 90 ft. dia. Type BX Eimco-Process thickeners at the mill of Milliken Lake Uranium Mines Limited, a member of the Rio Tinto group of uranium producing companies in the Algoma area of northern Ontario. These motorized devices provide operating flexibility in the washing circuit as they permit positive compensation for variations in the feed rate and ore characteristics or, if necessary, for the use of the thickeners as storage units during plant upsets.

Due to the corrosive nature of the leached pulp feed, each thickener mechanism is fabricated of Type 316 ELC stainless steel. A truss superstructure, resting on external concrete columns, supports the drive and raking assemblies. No hinged arms are used; when changes in the properties of the slurry tend to overload the mechanism, the complete raking assembly can be raised with the mechanism running, then gradually lowered as normal operation is resumed.

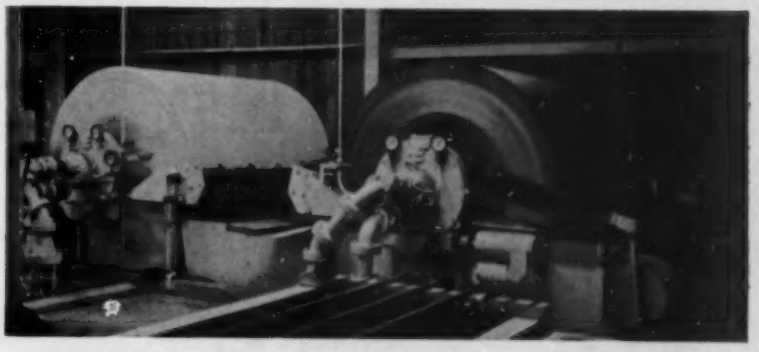
In the same mill, two 45 ft. dia. Eimco-Process beam supported units, also with stainless steel mechanisms, are being used to thicken the uranimum yellow cake slurry. Their underflow goes to one of the Eimco drum filter stations described below.



90 ft. dia. Eimco-Process heavy-duty thickener with motorized lifting device



45 ft. dia. beam supported unit used to thicken uranium yellow cake slurry



Acid leached ore is filtered by these high-capacity continuous drum filters

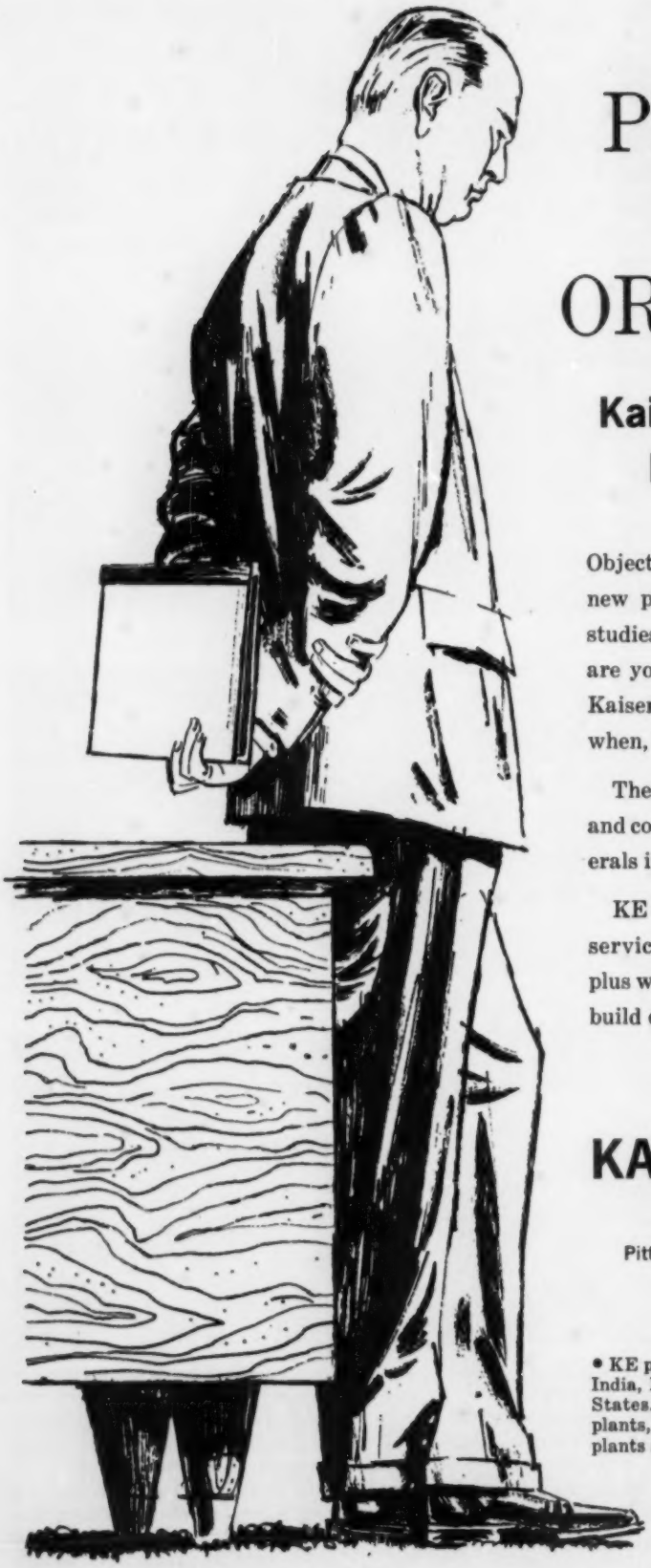
Rio Tinto Mill Also Uses 28 Eimco Vacuum Filters

To handle the many filtration problems involved in converting low grade uranium ores into the basic fuel of the atomic age, this mill also has installed a total of 28 Eimco vacuum filters.

Filtration equipment installed here includes drums, discs, and Agidiscs. All are high capacity continuous filters, and are used for filtering acid leached ore, uranium precipitate and neutral pulps.

Eimco equipment was chosen after first-hand observation of the fine performance of other Eimco filters in the area. Engineers at the mill had considered all types of equipment, but decided that Eimco filters could provide lowest soluble uranium losses and freedom from operational difficulties for this application.

180 Eimco filters are now operating in the Algoma uranium producing area of Ontario. Many more are in operation in other uranium mining areas throughout the world.



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Kaiser Engineers can help you decide

Objective analysis is vital to sound decision on new plant or expansion projects. Feasibility studies, economic analyses and site evaluations are yours by an outside, impartial firm when Kaiser Engineers is selected to help you decide when, how and where to proceed.

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5458-H

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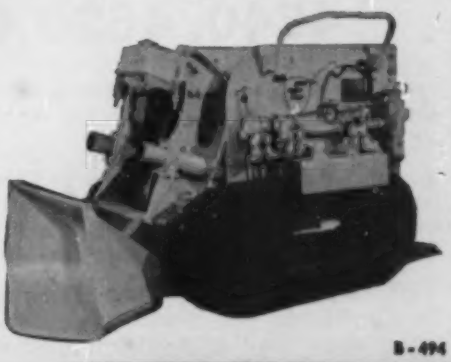
with the EIMCO 630 EXCAVATOR

Air or A.C. Electric powered, the versatile Eimco 630 Excavator can load 600 to 800 tons per shift, depending on rock and haulage equipment.

Available for headroom requirements of 6'-8" to 10'-7" (2030-3225 mm) and with overall width of just 5'-8⅝" (1745 mm), this trouble-free unit offers independent control to each track; has proven itself in the heaviest type of work in roughest areas, throughout the world.

Get all the facts! Contact the Eimco agent or dealer nearest you, or write The Eimco Corporation, P.O. Box 300, Salt Lake City 10, Utah, U.S.A.



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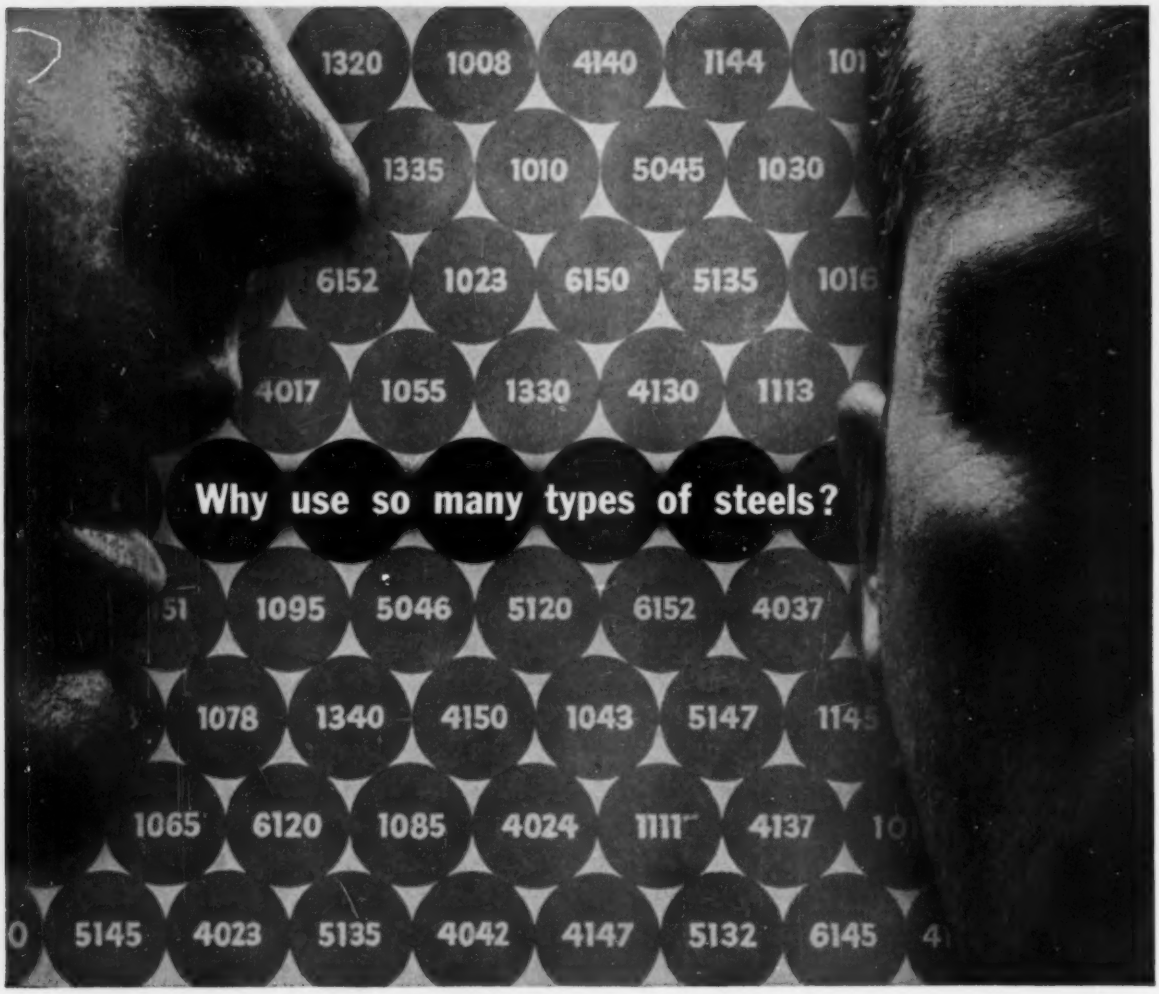

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4340, 4620 General Purpose Steels

You make your job easier and you standardize, simplify, and save money...

These two General Purpose alloy steels can solve most of your steel selection problems. One a carburizing type . . . the other a through-hardening type — with just these two alloy steels you can satisfy practically all your engineering requirements.

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When you need through-hardening steel, simply specify 4340. It's ideal for parts of any section size. It provides exceptionally high strength and toughness. Responds reliably to heat treatment. It's weldable under proper conditions and machines at relatively high hardness.

And when you want to carburize, simply specify 4620 steel. It resists warpage and distortion in heat treatment. Responds reliably and uniformly, too. Provides a tough, strong core to support the hard wear-resistant case.

Best of all, both are carried by Steel Service Centers from coast to coast, ready for delivery right off the shelf. If you need heavier-duty or special purpose steels for very particular applications, suitable nickel alloy steels are also available from your Steel Service Center. To get a buyer's guide of centers that carry 4340, 4620, and other nickel-containing grades, simply write Inco.

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MINING engineering REPORTER

U. S. Remains Top Mineral Producer

"The U. S. continues to lead the world in mineral output by a wide margin," according to a new USBM report detailing the world's nation-by-nation output in 1958. Russia, however, outstripped the U. S. in production of both coal and iron ore last year. Of the 63 commodities covered by the study, the U. S. is the top producer of 29. Russia leads in eight, Canada in three. Copies of the report, Bureau of Mines MMS 2979, "World Mineral Production in 1958," are available from the Bureau's Publications-Distribution Section, Interior Building, Washington, D. C.

Mount Isa Refinery to Step Up Capacity

The new Australian copper refinery of Mount Isa Mines Ltd., presently operating with capacity of 40,000 long tons annually, will hike output to 60,000 long tons through expansions recently started. The facility is near Townsville, Queensland.

Miner, Fabricator in Joint Zinc Venture

American Zinc, Lead & Smelting Co., miner and smelter, has joined Hydrometals Inc., metal fabricator, in an agreement to jointly develop and exploit zinc ore resources and facilities of Peru Mining Co., Silver City, N. M., and for American Zinc to cast, at Monsanto, Ill., 8000-lb ingots of a new titanium-copper-zinc alloy developed by Hydrometals. Peru Mining, Hydrometals subsidiary, has been inoperative for the past three years because of low zinc prices.

Copper Range Acquires Shares in Research Firm

Copper Range Co. has purchased "a substantial interest" in Alloyd Corp., a metals and materials research and development firm in Watertown, Mass. A joint announcement said "Research in recent years has led the metals and materials field into completely new and unexpected areas, resulting in opportunities for successful commercial development of new processes and materials. This new alliance will permit both companies to capitalize more effectively on such research and development." Terms of the acquisition were not disclosed.

Reynolds Barter: U. S. Wheat for Haitian Bauxite

In the midst of a world surplus of aluminum raw material, Reynolds Metals Co. has found an outlet for a heavy tonnage of the bauxite produced by its Haitian subsidiary, Reynolds Haitian Mines Inc. Over a one-year period, ore will be exchanged for surplus U. S. wheat—to be sent to a milling company in Haiti, under an agreement with the Federal Government—and the bauxite, some 400,000 tons of it, will be shipped to the U. S. strategic stockpile. The transaction, worth $6 million to $6.5 million, frees Reynolds to establish full capacity operations in Haiti, avoid the curtailments it had previously considered.

MINING engineering REPORTER

American Zinc Reactivating Two Mines

Start-up of two properties closed since December 1957 has been initiated by American Zinc, Lead & Smelting Co. The Piquette mine in Tennyson, Wis., owned jointly with Piquette Mining Co., is soon to be producing at the annual rate of 6000 tons of zinc concentrates and 600 tons of lead concentrates. The Grasselli mine at New Market, Tenn., is scheduled for early production of about 9000 tons of zinc concentrate yearly. Behind the renewed activity: zinc's price in late 1957 was 10¢ per lb; the current quotation is 12½¢.

No Renewal Contracts for Canadian Uranium

When existing contracts with uranium concentrate suppliers in Canada expire, no further agreements will be negotiated, the AEC announces. Aimed at holding down commitments in the post-1960 period (purchases already contracted for over the next few years will be bigger than requirements) and also at cutting expenditures, the plan foregoes the purchase options Canadian producers hoped would be exercised. To help ease problems, Canadian suppliers are being given the chance to stretch out deliveries beyond the normal 1962 and 1963 expiration dates. But quotas and prices remain the same as when the contracts were signed.

Steel Strike Injunction Brings Uncertainty

A Taft-Hartley injunction brought striking steelworkers back to their jobs but resumption of mill output posed problems. Ore boats getting under way on the Great Lakes may not be able to supply sufficient ore to winter stockpiles before freeze-up, furnaces down for repairs after the long strike will keep production at a low rate for some weeks, users will be short on supplies for some time, and expiration of the 80-day injunction may bring another walkout. Ore shipments have started up rapidly, however, and steel producers report light damages to furnaces. From operation at 12 to 13 pct of capacity during the 116 days of the strike, the steel industry had boosted output to an estimated 45 pct of capacity in first week back on the job.

Copper Price Climbs

The few copper producers still operating amid the industry strikes have hiked the price of the red metal by 1½¢, putting the new quotation at 33½¢. About 80 pct of U. S. mine output has been cut off by walkouts.

Secrets of Diamond-Making Disclosed

General Electric's Research Laboratory has explained its method of manufacturing synthetic diamonds. The company uses a catalyst metal—any one of a dozen elements, including iron, cobalt, nickel, osmium, platinum—in conjunction with graphite. The graphite and catalyst are placed in a cemented carbide chamber and subjected to pressures from 800,000 to 1.8 million psi and temperatures from 2200° to 4400°F. The diamond product is turned out in only minutes.

marcy mills...

"No Compromise with Quality"

YOUR ASSURANCE OF

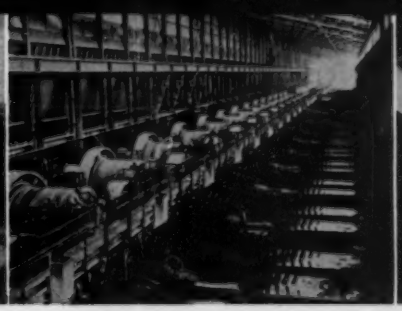
▶ **low net-cost-per-ton grinding**

AND

▶ **long operating life**

Since 1915...

seven 8'x 6' Marcys, purchased in 1915 by a U. S. copper company, are now being used in a Philippine Island mill. After 43 years these mills are still operating with their original gears.



For 15 Years...

these 10'x 10' Marcys have been operating in a large copper mill. There have been no bearing problems and the original gears are just now being reversed.

Since 1915...

this 8'x 6' Marcy is still working 24 hours per day in a large cement plant after 43 years of dependable mechanical operation.

Manufacturing Division

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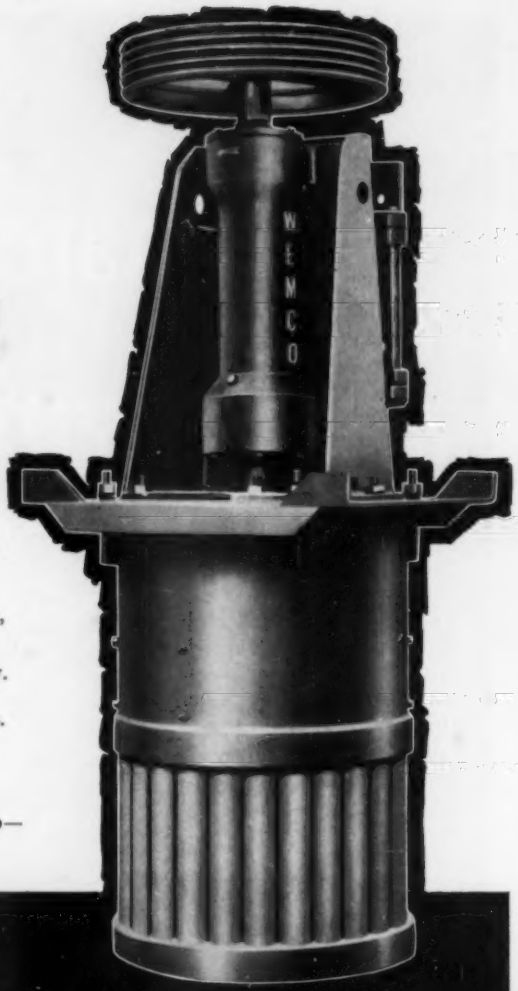
THIS DECISION WILL PAY BONUS PROFITS OF MORE THAN $6,500 EVERY DAY!



This order and installation of Wemco-Fagergren Flotation Machines by a leading coal producer will result in additional profits of over *$6500 per working day*— and for surprisingly low capital investment. Cost of the total plant addition, including the flotation cells, will be offset in less than four months.

This is another example of how Fags go to work—profitably. Recovery is consistently higher; floor space, maintenance and operating labor, reagent and other requirements are less.

The Wemco-Fagergren record of profit-producing installations tells the story of sound experience. The men of Wemco will be glad to furnish all the facts and discuss why Wemco-Fagergren Flotation will do a better job—where flotation has a place.

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a division of
Western Machinery Company, 650 Fifth St., San Francisco, Calif.
and throughout the world

5 reasons why Atlas Copco's "TIGER" is best for stoping and all short-hole drilling!

(1) It's fast and easy to handle!

(2) It's easy collaring, with little recoil!

(3) Features a retractable air leg!

(4) Convenient controls, automatic back head!

(5) Operates on single air supply!

Here's the TIGER—a new, fast, compact rock drill with power and stamina to meet toughest drilling requirements! Its high percussion rate not only speeds penetration, but at the same time cuts recoil to a minimum. With controls conveniently located, collaring is unusually easy.

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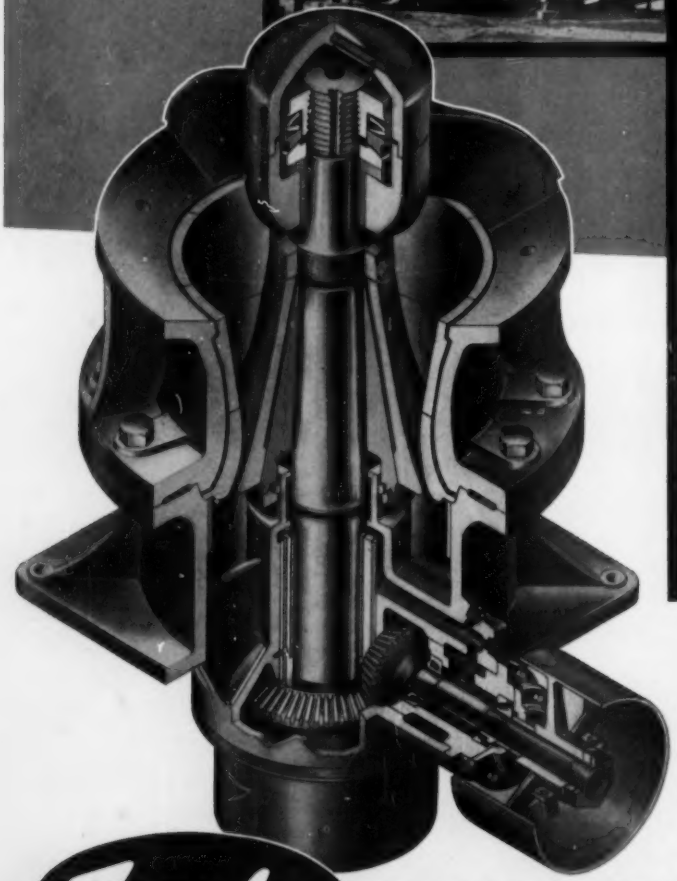
type **TY** gyratory crusher

for secondary reduction

Shown at left is a 3'-0" Traylor Crusher in a rock and gravel producing plant. Above - 2'-4" TY Crusher in operation at sand and gravel plant.



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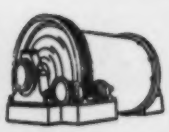

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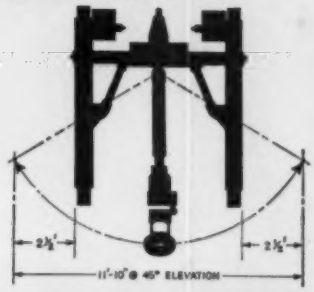
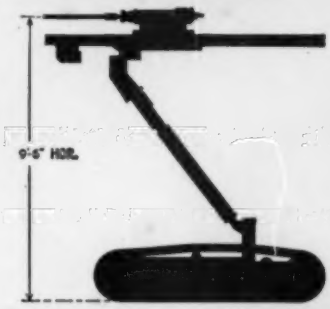


...MORE REACH



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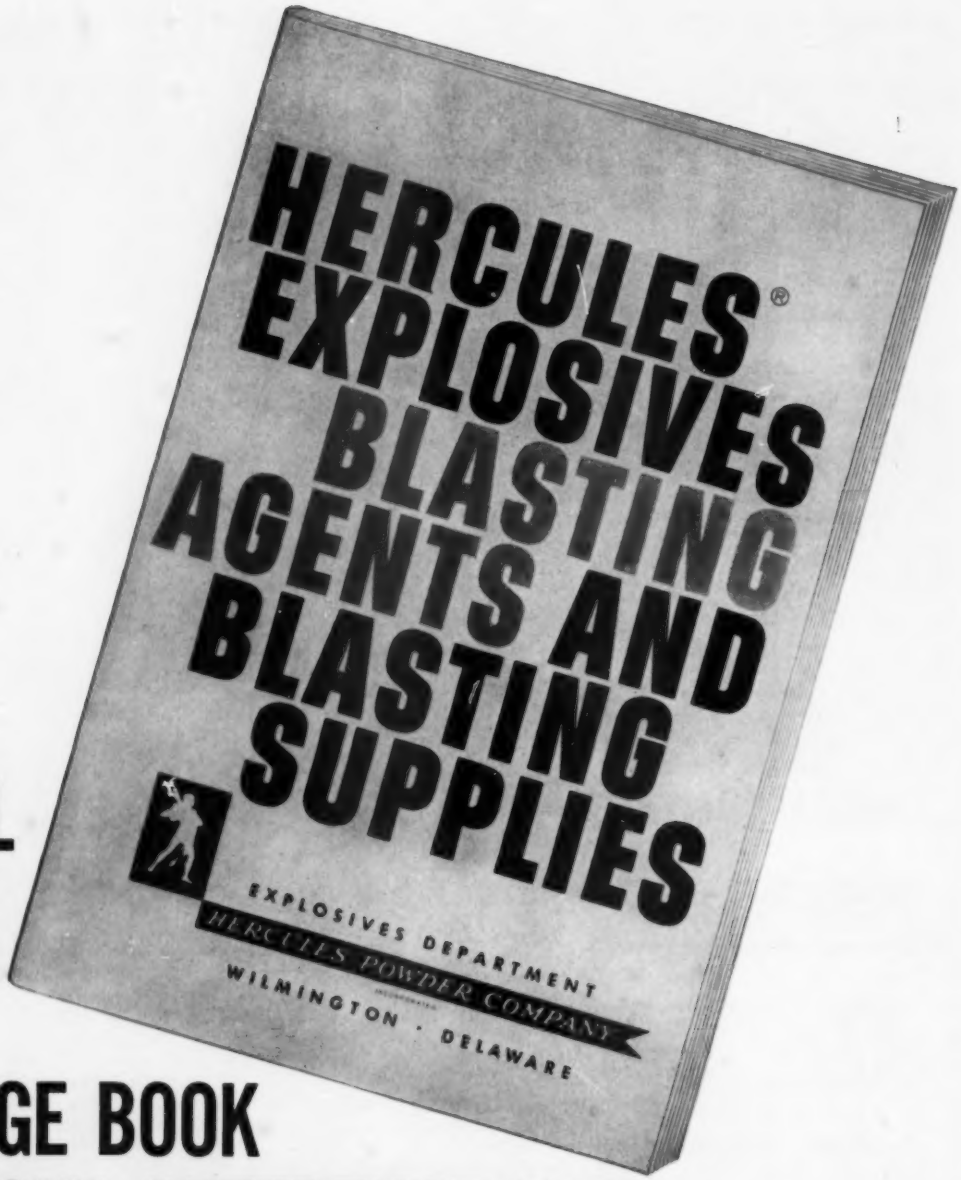

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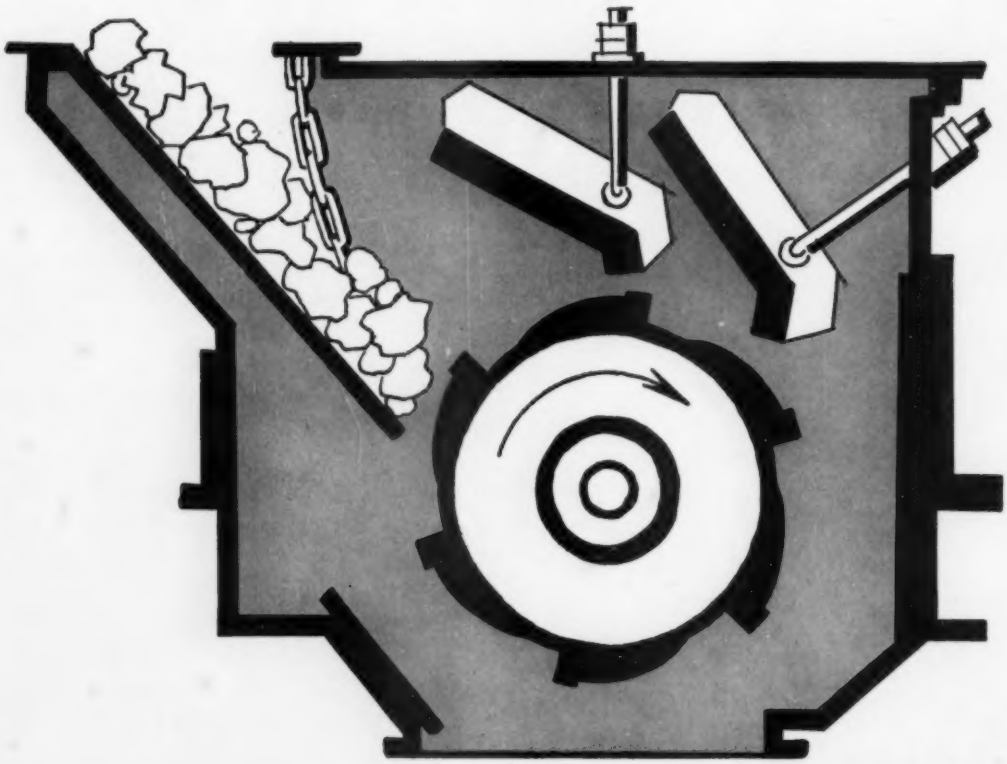

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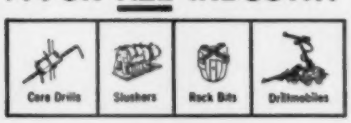

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MINING engineering **DRIFT**

ABSTRACTS, PREPRINTS, AND SCHEDULES

In this issue you will find abstracts of a majority of the Annual Meeting papers. Some of the program forms with these abstracts were received by deadline, some were late, and some were very late. Our thanks to those who sent their abstracts in on time, for they made possible the handling of some of the very late comers. The January issue of MINING ENGINEERING will, of necessity, carry a *second section* with the late abstracts, or as many as are available.

We had hoped this year to have all the abstracts to publish in the December issue. This was to serve two purposes: First, to present a timely preview of the entire SME program in enough detail for members to decide that the trip to New York is worthwhile. Second, to help conserve needed Society funds by overrunning only a single section for meeting use.

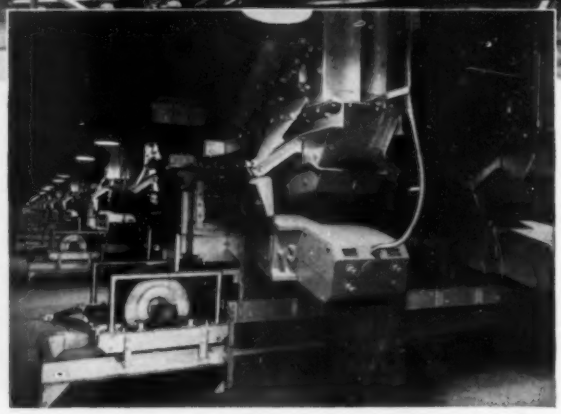
To hold off the entire section until January would satisfy the second purpose, but defeat the first—and possibly more important—purpose.

A meeting this February of incoming and retiring program committees is planned. At this meeting the 1959-1960 program committee will brief the 1960-1961 committee on what to do and what to avoid doing. The 1960-1961 committee, thus forewarned, will get an early start on plans for the February 1961 Annual Meeting to be held in St. Louis.

But, advance planning is worthless without timely execution. And timely execution is utterly dependent on the full cooperation of the invited speakers.

• Meetings are not held unless there are hard-working committees, articles are not written unless authors do it, and the magazine wouldn't come out without a helpful printer. By the end of each year we owe a great debt to all of these people. To these, and the many others whose friendly interest is vital to AIME, SME, and ME: Thank You, and Seasons Greetings from the staff of the Society of Mining Engineers.

Jeffrey magnetic separators help raise iron content of pellets to 64%.



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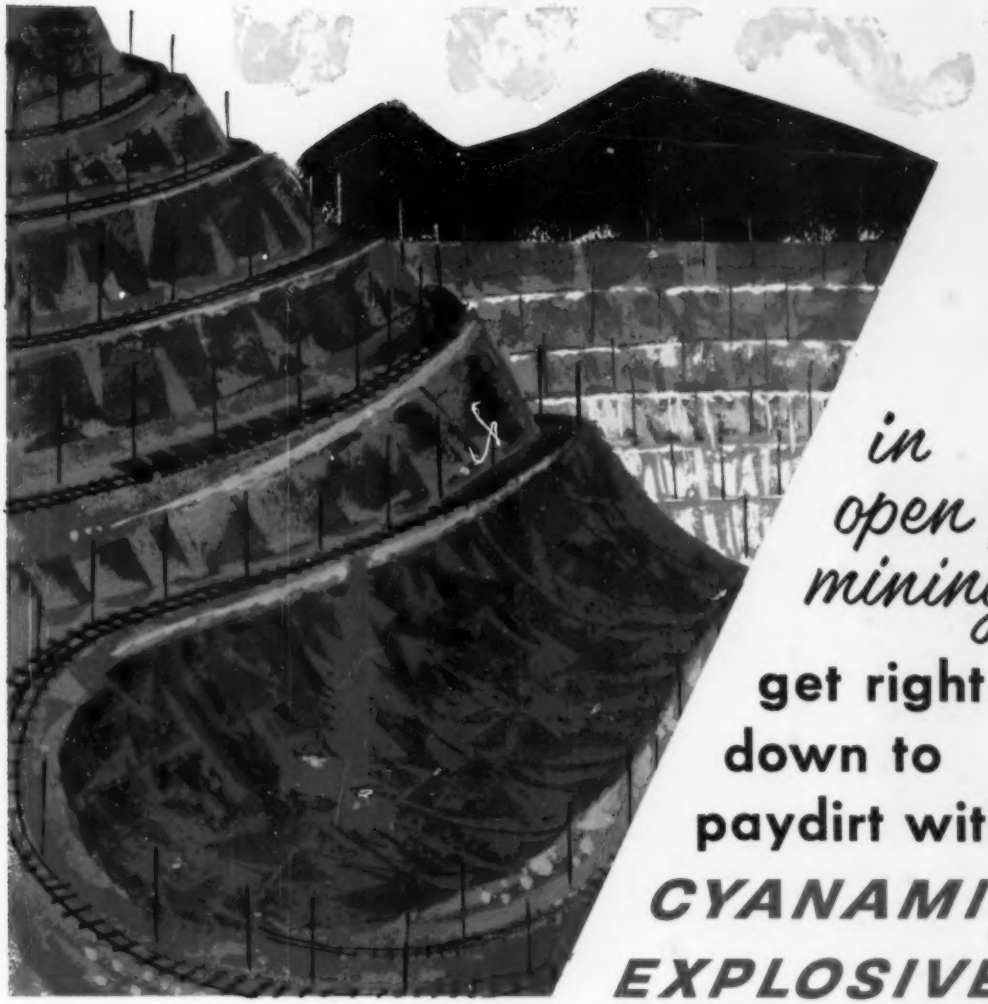

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Schedule
SOCIETY OF MINING ENGINEERS
Technical Sessions

February 14 to 18, 1960
Statler-Hilton Hotel
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Sunday, February 14, PM
Council of Education—*Discussion*

Monday, February 15, AM
Coal Div.—*Session*
IndMD—*Rare & Radioactive Minerals*
MBD—*Comminution Symposium*
M&E Div.—*Open Pit Mining*
SEG—*Session*

Monday, February 15, PM
Coal Div.—*Session*
IndMD—*Industrial Waters*
MBD—*Concentration*
M&E Div.—*Underground Mining—Geophysical*
Counc. of Econ.—*Fuel Economics*

Tuesday, February 16, AM
Coal Div.—*Session*
IndMD—*Abrasives & Fillers*
MBD—*Solid-Fluids Separation*
M&E Div.—*Geochemical*
—*Rock Mechanics—Open Pit*
Counc. of Econ.—*Mineral Economics*

Tuesday, February 16, PM
AIME—*All-Institute Session*
—*Annual Business Meeting*

Wednesday, February 17, AM
Coal Div.—*Session*
IndMD—*Ceramic Raw Materials*
MBD—*Materials Handling & Mill Design*
—*Surface Chemistry Symposium (Joint MBD, EMD, IMD)*
M&E Div.—*Underground Mining*

Wednesday, February 17, PM
Coal Div.—*Session*
IndMD—*Chemical Raw Materials*
MBD—*Operating Control*
—*Surface Chemistry Symposium (Joint MBD, EMD, IMD)*
M&E Div.—*Jackling Lecture*

Thursday, February 18, AM
Coal Div.—*Session*
IndMD—*Cement, Lime and Gypsum*
MBD—*Magnetic Roasting of Iron Ores*
M&E Div.—*Geological*
Counc. of Econ.—*Symposium: Incentive Method*

Thursday, February 18, PM
Coal Div.—*Session*
IndMD—*Dimension Stone and Slate with Mineral Aggregates (Joint)*
MBD—*Chemical Processing*
M&E Div.—*Geological*

CALENDAR OF EVENTS

Sunday, February 14
Council of Education—Buffet Supper

Monday, February 15
AIME Welcoming Luncheon
AIME Cocktail Party
AIME Dinner—Smoker

Tuesday February 16
Minerals Beneficiation Division—Scotch Breakfast
Luncheons: Industrial Minerals Division
Coal Division
Council of Economics
Mining & Metallurgical Soc. of America
Society of Mining Engineers—Dinner
AIME Informal Dance

Wednesday, February 17
Luncheon: Mining & Exploration Division
AIME Annual Banquet

Thursday, February 18
Luncheons: Minerals Beneficiation Division
Society of Economic Geologists

All Social Events listed as well as AIME and SME headquarters and registration will be in the Statler-Hilton.

ABSTRACTS OF ANNUAL MEETING PAPERS

Society of Mining Engineers

October 20th was the deadline for abstracts to be published in the December issue. Additional abstracts received before the closing date for the January issue will be published in that issue. Publication of abstracts does not indicate Preprint availability. An Available Preprint List, by number, will appear in the January issue. **Do not order papers until this list appears.**

COAL DIVISION

Continuous Mining

Daily Maintenance and Complete Overhaul of Continuous Miners by *Joseph Mason*—Today's continuous miner is a precision built, highly complex machine. The potential capacity of the miner is such that one minute delay means from 3 to 7 tons of coal lost.

This paper deals with a preventive maintenance program in which every phase of downtime prevention, overhauling, and daily repair is planned to care for A.C. and D.C. miners operating on a 3-shift basis. The paper tells how visual indicators, test devices, and test facilities are installed and applied to promote the basic maintenance functions of checking, servicing, adjusting, replacing, and trouble shooting.

The paper discusses unit changeout or package assembly system of repairs and overhaul and how mobile repair units handle the lifting jobs of inaccessible, bulky machine parts in the crowded working quarters of the underground face area.

It discusses the very latest developments in cutting chains, bits, bit blocks, and bit block attachment with regard to their application in the overall maintenance picture.

The care and trougie shooting of trailing cable is also covered.

This program has helped us reduce cost in our operation in which 70% of our total output comes from continuous miners, and I'm sure it will help others.

Selecting the Proper Type of Continuous Miner by *John A Stachura*—The underground mining industry is now repeating history which took place in the early 1920's. At that time a change was taking place from hand loading to conventional track and off track mechanical mining. There was much opposition to this change and as expected, many problems to be worked out. After a few years it reached a point where any company that could purchase the equipment did produce coal more economically with this new equipment. Today continuous mining is experiencing the same growing pains. The major problems to date appear to be proper size consist for each operator's particular market. Building the machine to get maximum operating time with a low maintenance cost. Providing proper roof control while the machine is mining in order to reduce lost time moving from one place to another. Building in enough flexibility to permit mining of coal seams where the heighth varies as much as two or three feet in the same mining area, plus numerous other problems resulting from conditions that are different from one mine to another in the same mining area. Although there has been some progress made to date in solving these problems, the increased use of the continuous mining machines will permit more rapid progress toward a solution of the safety and economical problems which plague the industry today.

Moss No. 3 Mine: The Materials Handling Aspects by *F. M. Morris*—A Large reserve of thick coal in Southwest Virginia was developed by Clinchfield Coal Company, Division of The Pittston Company in 1957-1958 to produce a nominal rate of 1500 tons of raw coal per hour. Operation features coal cleaning in transit. Refuse removed averages 35%.

Motion picture and paper will describe: (a) Transportation of raw coal from four mine portals at Duty, Virginia, using 48" and 36" belts, conveying to two separate railroad loading points, each with storage facilities for 240 loads and 240 empties. (b) Norfolk & Western Railway facilities and equipment required to transport 500 cars of raw coal per day 8 miles from mines to Preparation Plant (c) Dumping, crushing and raw coal handling facilities to Preparation Plant at Carbo. (d) Final disposition of refuse by belt conveyor, fixed stacker, trailing conveyor and movable stacker.

Paper discusses evolution of plant from initial concepts to completion, explains selection of means applied and describes performance to date versus design expectation. Plan calls for ultimate handling capacity of 40 thousand tons of raw coal per day with anticipated clean coal capacity of 26 thousand tons per day, on three shift basis. Project features: large shuttle cars, feeders and heavy duty rope belt conveying equipment at mines; automatic car retarding system and elaborate sampling facilities at preparation plant; employs track mounted stacker and trailing conveyor and turn-over belts on refuse disposal system.

New Gadgets, Methods and Equipment

Mechanized Tie Tamping of Haulage Road by *David H. Davis*—The job of tamping ballast under the ties of an underground haulage road is laborious and expensive. In the past this has been done by hand tools and in some instances by a pneumatic hammer held and operated by a single workman. Sometimes as many as four men are used in the tamping operation and the distance tamped is limited by the fatigue of the men. Railroads have mechanized this phase of track construction and greatly reduced cost and increased output.

This paper describes the operation and construction of a mechanical device adapted for the tamping of ballast under the ties of a track using heavy rail laid for modern high speed haulage in coal mines. Certain data is to be presented indicating what can be accomplished by the use of this machine.

Tube Furnace Method for Rapid Determination of Sulfur in Coal by *G. Dale Coe*—This paper gives the details for an improved technique for the determination of sulfur in coal by burning a half-gram sample in oxygen in a tube furnace at 2400°F. The gaseous products of combustion are bubbled through a dilute hydrogen peroxide solution wherein the sulfur that was present in the coal is converted to sulfuric acid. The acid is titrated with a standardized alkali solution. About 5 minutes are required for the determination. Analyses by both the Eschka and Tube Furnace methods are compared for different coals. Interference of chlorine is discussed.

Continuous and Automatic Measurement of Moisture in Coal by Capacitance by *Loy A. Updegraff*—Measurement of the moisture content of free flowing solids on a continuous basis by capacitance is a process which has only recently been placed on the market. It was first developed for use in the food industry where the control of moisture in various processes is of vital importance to the manufacturer. In this industry the system is used to automatically measure, record, and control the moisture of certain bulk solids and has proven to be quite accurate. Early in 1958, Bituminous Coal Research, Inc., set up a research program to adapt such a system to the coal industry. The necessary laboratory equipment was obtained and experimental work started in March. Results looked so promising that it was soon decided that field tests would be in order. The equipment was then taken from the laboratory to a large preparation plant where the ¾ x 0" coal is dried in thermal dryers. Instead of using a measuring cell through which a small stream of coal was passed, as had been done in the laboratory, BCR designed an electrode plate to replace the cell which could be installed in a stationary position submerged in a moving stream of coal either on a loading boom or a belt. Results were very gratifying and more units will soon be in operation in other preparation plants.

Preparation

High Head Slurry Pumping by *W. D. Haentjens*—The paper traces Barrett, Haentjens and Company's development and application of centrifugal slurry pumps for series application. Convinced that large economies for users could be obtained by placing all pumps at one location—in comparison with the then accepted method of locating pumps along the pipeline—pumps were developed for ever increasing total heads. Starting in 1944 with two 2500 gpm units in series for 300' head, the development has continued with installations in service at almost 900', and units under construction for 1200'. The pioneering work of this company should open many new fields of hydraulic transportation using centrifugal pumps.

Crushing of Anthracite for the Reduction of Domestic to Steam Sizes by *H. B. Charmbury, P. O. Rao, and D. R. Mitchell*—Laboratory and pilot plant tests have been conducted to investigate the technical feasibility of using any one of four types of commercial crushers to reduce the domestic sizes of anthracite to steam sizes. The crushers tested were the rotary breaker, the aerofas mill, the jaw crusher and the impactor. Results are compared with the current practice of using multistage roll crushers.

The rotary breaker of the Bradford type was found to have numerous advantages and flexibility but in order to obtain a reasonable amount of the steam sizes the percentage of original material reduced to the fines was considerably larger than that obtained with current roll crusher procedures.

The aerofall mill was found to reduce all particles to the extreme fine sizes of No. 4 and No. 5 buck, even under the mildest crushing conditions. In fact, this type of mill could be recommended for the reduction of domestic sizes to sintering and pulverized fuel sizes.

Pilot plant tests with the jaw crusher confirmed laboratory experiments and indicated that the jaw crusher could be used for proper size reduction. The amount of extreme fines produced was slightly larger than with rolls but the single stage operation requiring minimum material handling would more than compensate for the additional fines.

Impactor crushers were also found to be satisfactory for this problem. These crushers have a large number of variables making it possible to have greater flexibility in the size consist of the crushed product.

Utilization

A Field Study in Acid Mine Drainage by *J. Richard Lucas*—Report on the progress of an Acid Mine Research project for the alleviation and control of acid mine wastes. Field studies were initiated and a test mine was sealed in Southeastern Ohio for controlled air sealing and water flooding studies. A versatile mine seal was constructed permitting instrumentation and physical access to the mine through the seal.

The Exploration and Mining of Raw Materials—Production of Refractory Products—Application for the Utilization of Coal by *O. W. Kamper*—This paper will deal with the exploration and mining of refractory raw materials, the manufacture of refractory products and the application in the utilization of coal. The necessity for extensive raw materials exploration to develop reserves for forty company plants distributed across the United States, Canada, Mexico and South America and problems connected with the selection and mining of clays and silica will be explained. Quality control and its effect and benefit in mining and in refractory products manufacture will be discussed. Manufacture of refractories will be explained commencing with the entry of raw materials into the plant and ending with the finished product ready for customer service. Finally, a discussion of the various applications, such as ovens, boilers, heaters, etc., where the refractory products are used in the utilization of coal.

Ventilation of Very Gaseous Mines

Ventilation of Conventional Development in Gassy Coal Mines by *Leonard Sargeant*—A brief discussion of methane liberation in the Pocahontas Field will be followed by a detailed explanation of ventilating a typical development section operating with conventional mining equipment. Talk will cover coursing of air, ventilation construction standards, mining cycles and safety procedures. The development of main entries, panel entries, panels and bleeder entries will be outlined. A short discussion of air measurements, air samples and analysis, ventilation reports and inspection practices will conclude this paper. (Subject to revision)

Face Ventilation In Development With Continuous Miners by *William Poundstone*—Paper will deal with the mining and ventilating system used in development work in the Pittsburg Seam in Northern West Virginia. The seam conditions and the nature of the accompanying methane gas will be described. The type of equipment and the mining cycle will be discussed, showing how they are well suited for very gaseous development work.

Efficient Pillar Extraction by Means of Exhaust Ventilation by *Lonnie D. Ellison*—*Effective Mine Ventilation—One of Coal Industry's Most Pressing Problems.* Constant improving of mining equipment demands the continual change of means and methods of control ventilation as discussed in this paper. Adequate ventilation to dilute and move 12,000,000 c.f. of methane per day requiring 1,200,000 c.f.m. at I.C.C.Co's Bartley No. 1 Mine, is achieved by use of line brattice, check curtains, temporary and permanent stoppings, doors, regulators, and overcasts.

Use of different types of mining equipment on various sections presents different problems to dilute the methane to less than 1% at the face or point of emission of the gas. The use of continuous miners presents more of a problem in ventilation than does the use of conventional equipment. The large machine nearly filling the advancing face tends to prohibit air reaching the most important point—the point of gas emission. Bleeder entries provide means for continued bleeding of pillared areas and daily sampling of return air provides information by which effective ventilation can be and is maintained.

One must be constantly aware that no two mines or even different parts of the same mine can be ventilated by a rule and thumb method.

Ventilation of Very Gassy Mines Making Use of Large Diameter Bore Holes by *David C. Ridenour*—The Olga Coal Company has made effective use of a large diameter bore holes in ventilating gassy mines in the No. 4 Pocahontas Coal Seam in McDowell County, West Virginia. To date, five large bore holes have been drilled and are being used to ventilate active pillar workings and to serve as bleeders for gob areas. By causing a positive flow of air over the gobs away from the working places, these holes have reduced delays due to ventilation and reduced the amount of coal needed to be left in for bleeder pillars.

COUNCIL OF ECONOMICS

Fuel Economics

Use of New Productivity Measure to Qualify the Petroleum and Natural Gas Industry's Contribution to an Expanding National Economy by *Virgil L. Barr*—National Income Originating compared to physical production for an enterprise or an industry reflects its ability to strengthen the national economy. For a single industrial sector or industry, this comparison can be useful to summarize changes that may occur in this ability to contribute because of changing supply-demand-income-investment equilibria. A favorable relationship can be assumed, and the technologic input accompanied by specified economic incentive required can be shown.

The constant dollar income originating in the petroleum industry divided by Federal Reserve Board indexes of production provides an index that reflects increases or decreases in productivity. When compared with other mineral industries and with total industry, an approximation of relative strength is evident.

Constructing three different hypothetical conditions for future imports, assuming a constant excess capacity requirement, and providing an estimate for future domestic demand for petroleum, the impact on the productivity index can be shown.

Thus, a strong position for the petroleum and natural gas industry can be stated. If this is done it becomes evident that because of restrictions on cost-price relationships, a drilling program that would provide enough oil to meet demand may not be practicable. By difference, the amount of improvement in methods of production and processing can be stated explicitly.

A Method of Projecting U. S. Petroleum Supply by *Paul W. McGann*—The method of projecting petroleum supply used here may begin by assuming certain production (or capacity) needs. Next, one estimates the new oil wells needed to provide the capacity needs on the basis of: 1) declines in capacity resulting from production, 2) new oil well capacities, and 3) increased capacity per producing well. Producing oil wells and cumulated oil wells are next projected on the basis of new oil wells and capacity per producing well.

Historical relations between cumulated oil wells and certain variables are used to project: average depth, the ratio of total new wells to new oil wells, the dry hole ratio, total crude oil found per new oil well, new pool oil discovered per exploratory well, and the ratio of exploratory wells to all wells. From these projections one may compute total footage drilled, new pool crude oil discovered, and crude oil added to reserves from extensions and revisions.

Extrapolation of the historical relation between footage drilled and total field revenues (in constant dollars) from oil and gas is used to project revenues needed to finance projected footage.

Prices and U. S. production rates as computed in the foregoing are compared with extra-polated values of the regression line between historical statistics of crude oil price (in constant dollars) plotted against U. S. petroleum production for 1943-1958. This latter type of historical-statistical relationship differs significantly for various states and foreign nations.

The supply-price relationships can be usefully combined with demand-price relationships to find effects of changing circumstances upon price and quantities demanded and supplied.

The Question of Governmental Oil Import Restrictions by *William H. Peterson*—Study of the argument used by the Government and the independent domestic oil and coal producers fails to find adequate cause to justify governmental oil import restrictions through the use of import quotas. Quite the contrary, study of the program in practice indicates that it is harmful to the foreign relations of the United States, disruptive to the defense position of the armed forces, depletive to domestic crude oil reserves, injurious to the long-run vitality of the American oil industry both at home and abroad, costly to American consumers, and finally it establishes precedents for further governmental intervention incompatible with the precepts of a free society.

For these reasons, it is recommended that moves be instituted to disestablish the entire quota program, whether voluntary or mandatory, as expeditiously as possible. To ease hardship on operators of marginal wells, stripper and otherwise, the term of disestablishment might be extended over a three-year period.

Trends in Property Acquisitions and Mergers in the Oil Industry Since 1954 by *H. Marshall Farrier*—Recently, property acquisitions and mergers involving United States or Canadian oil companies—whereby one company acquired part or all of the assets and liabilities of another—have been taking place at a very accelerated pace. Initially, most of these property exchanges involved crude reserves. Recently, however, very increased emphasis has been on acquiring refining and marketing properties. These facts are substantiated by a table showing the number and type of property transfers in the petroleum industry which have been reported by public sources since January 1, 1954. The paper also a) presents a brief discussion of some of the economic conditions existing in the petroleum industry which have stimulated, and which will probably continue to stimulate, property consolidations; b) presents a brief discussion of some of the reasons why recent emphasis has been on acquiring marketing and refining companies; c) enumerates and briefly discusses the financial methods which have been employed to consummate these property transfers; and d) briefly discusses the public desirability of acquisitions and mergers occurring in the petroleum industry. The above presentation will be followed by a summary of the report with some conclusions as to the rate that acquisitions and mergers might be expected over the next few years.

Bituminous Coal Consumption—Estimating Its Long Term Growth and Annual Variation by *John J. Schanz, Jr.*—The greatest share of the phenomenal growth in energy demand can be attributed to two markets—gasoline and electricity. The remainder of the total energy market shows remarkably slow growth. In effect, the increasing efficiency of fuel utilization nullifies much of the effect of a growing population.

An examination of the markets for bituminous coal discloses that the deterioration in certain market sectors has about run its course, and the future consumption will depend primarily on the demand for electricity and coke. The use of coal by "other industrial" appears to have stabilized and will remain virtually constant. The consumption of bituminous coal has been estimated for the period 1960 to 1970 taking into consideration trends of total energy use, growth of electrical demand, and relative changes in the use of fuels in generating electricity.

Since bituminous coal consumption has shown wide fluctuations, which makes short terms estimates difficult, correlations have been made between coal consumed for coke and electricity and gross national product and "other industrial" consumption and the index of industrial production. Using the above correlations, a single equation is developed which can be used to calculate annual changes in bituminous coal consumption.

Mineral Economics

World Trade In Metal Raw Materials by *John D. Ridge*—Tables showing world trade in metallic mineral raw materials during the years 1953 through 1957 have been prepared for the following twenty-one commodities: alumina, aluminum, bauxite, chrome ore, copper ore and concentrates, unrefined and refined copper metal, iron ore, pig iron, steel (simple shapes), lead ore and concentrates, lead metal, manganese ore, mercury, nickel ore, concentrates, and matte, nickel metal, raw pyrites, sintered pyrites, tin ore and concentrates, tin metal, zinc ore and concentrates, and zinc metal. In each instance, the amounts given by the importing country have been used except when statistics from the importing nation are not available. To show the considerable divergence between importing and exporting country totals for the same years, the mercury table shows in parallel columns the comparable figures of importer and exporter. This table is given in the paper. The twenty-one tables are used as a basis for testing the thirteen rules governing trade in metal raw materials which I first published in Mining Engineering in July, 1955. The 1953 through 1957 data on which the present paper is based are more extensive, both in time and commodities considered, than the 1952 data used for the 1955 paper, but the changes required in the rules are small, and in general their validity is confirmed.

U. S. Strategy and National Stockpile Programs by *John D. Morgan, Jr.*—The USA must be prepared for 1) political or economic warfare, 2) limited war, or 3) all-out nuclear, biological, or chemical attack upon us. U.S. stockpiles are based on several laws, including the Strategic and Critical Materials Stockpiling Act, the Defense Production Act, the Federal Civil Defense Act, several special Mineral Acts, and several Agricultural Acts; and the criteria for accumulation, retention, and disposal vary greatly under the different Acts. The present Government organization of agencies for defense plans and programs including stockpiling. Determination of stockpile objectives and relation to other programs. The present status of U.S. stockpiles. Special problems involving high-temperature and other special property materials needed for new or improved materials applications in military, atomic energy and space programs. Recent barter activity. The threat of stockpile disposals. The long-term outlook.

Incentive Symposium

The Butte Contract System by *V. D. O'Leary*—The agreements between The Anaconda Co. and its miners are not contracts in the true sense of the word. They are tacit agreements in which the Company supplies the opportunity and the equipment while the

miners furnish the labor for the ultimate purpose of benefitting both parties.

Prices are not discussed at hiring, but can be after the contract has started operating. Prices are set from schedules which were founded on the years of experience of operating staffs and engineers on what constitutes a fair day's work. The schedules are flexible enough to meet changing physical conditions. They are adjusted when newer mining methods, or newer equipment, makes it imperative.

Miners can be critical of measurements, can demand re-measurements, and, if they wish, can process any complaint through the normal grievance procedure. They can discuss conditions and equipment, as well as prices, with the mine superintendent.

The mine superintendant is in full control of prices, and he has considerable latitude in the way he handles his contracts. However, he is limited by contract costs, and must be prepared to justify unusual actions.—The Butte contract system has proved to be popular with miners and has been very successful in its operation. It can only remain so as long as the company retains full control.

Incentive Pay System at the Homestake Mining Company by *Joel K. Waterland*—The Homestake Mining Company has been in active production since 1876, and has used an incentive pay system since 1916. This system has developed down through the years until at the present time all work is contract, except haulage and maintenance. A sliding scale of three prices designated as "A"—"B"—and "C" has been set for each of the mining categories, with special prices to be applied where the work that is being done is not covered by the general price. From these gross earnings, the miners are charged for a portion of the explosives used, and are also charged for mistreatment of air and water hoses. The contract system has proved highly successful, as the number of supervisory employees has been reduced, and a remarkable increase in production per man-shift has been noted. The resulting higher earnings has added greatly to the labor relations between the men and the company.

Foremen's Incentive Plan by *Arthur E. Belton*—The objective for any part of an Industrial Engineering Program is to increase productivity and reduce unit cost. One should think of an incentive program as the top rung of the Industrial Engineering ladder. The following steps are necessary: 1) secure basic time data; 2) establish method and work load; 3) develop section and mine production standards; 4) develop mine labor budget and labor cost standard; 5) set up an effective maintenance program; 6) provide a foremen's incentive plan. Because of the inherent nature of mining, the foreman exercises more direct and effective control over cost than anyone in management. It is the foreman who is in direct control of the men, machines and material. If a company is to be a leader in its field and meet competition, all three of these resources must be used efficiently. The whole system must have adequate meaning and an objective for the people who must work with it. Therefore, it is imperative that the Industrial Engineer work very closely with the local mine management. A Foremen's Incentive Plan is actually a tool to assist top management to perform its job with a high degree of efficiency. However, no tool can achieve its intended purpose unless it is skillfully used.

Production Management Incentive Compensation System at IMC by *Morley H. Mathewson*—The unprecedented demand for capital investment in the mining industry today has intensified management's interest in every known technique which will help to reduce operating costs and increase production.

One proven approach leading to the accomplishment of this objective is well known in the mining industry and is gaining added prestige, particularly where keen competitive conditions exist. This approach is in the area of incentives applied to mining productivity.

An investigation of many incentive plans now in use throughout the mining industry revealed a predominant number of conventional type plans. Most of these plans are designed to reward the hourly paid employee on the basis of percent over and above a standard hourly or daily ton rate. By contrast, this search failed to divulge any incentive plan solely and independently developed for supervisory employees. This does not mean that such plans in the mining industry are nonexistent, but it does indicate that supervisory incentive plans are scarce or are being kept under wraps.

An attempt will be made to help lift this veil, if such a condition exists, by discussing the two factors that are so essential to the successful development of a supervisory incentive plan. *First, the importance of the philosophy of management will be reviewed, and second, the need for a sound Industrial Engineering approach will be evaluated.*

Minerals and Monopoly—Formula for Soviet Success by *Alexander Gaknet*—Ownership of the natural resources, together with monopoly of labor, technical personnel, investment capital, domestic markets, and foreign trade, has enabled the government of the U.S.S.R. to direct a concentrated effort toward the discovery and development of the country's great mineral wealth. Production of indigenous mineral raw materials for domestic consumption as well as for foreign trade has reached enormous proportions. The U.S.S.R. now accounts for over one-sixth of the world's mineral output by value and is the most self-sufficient of the leading industrial nations. About one-third of the Soviet foreign trade by value is in minerals and metals. Yet, while some segments of our own preeminent mineral industry are rapidly approaching "old age," the mineral industry of the U.S.S.R. is still looking forward to vast untapped resources as the current Seven-Year Plan calls for accelerated production of minerals and metals. The paper analyzes the growing threat this Soviet position of strength through minerals poses to the economies and international markets of the nations of the Free World.

Rich Mineral Resources Spur Communist China's Bid for Industrial Power by *K. P. Wang*—Within one decade Communist China has achieved startling results in developing its rich mineral resources. Exploration has been on a scale the world has seldom seen. Rapid strides are being made in technology, exemplified by modern iron and steel furnaces, efficient hydraulic and cutter-loader coal operations, and mineral products meeting marketing specifications. Even the defunct backyard furnace program was instrumental in accumulating iron material and in providing essential data for establishing large-scale plants. The move to develop small-scale local industries —coal, steel, oil shale, cement, chemicals, fertilizers, and metal workshops—is aimed at reducing transport charges and making best use of low-cost manpower.

The country has long been famous for its antimony, tungsten, and tin. However, other Chinese export minerals like mercury, bismuthinite, manganese, molybdenite, fluorspar, talc, and magnesite also are beginning to exert themselves in world markets. Simultaneously, basic mineral industries essential for industrialization are being greatly expanded. Coal output now ranks third in the world, and steel output about seventh. Cement production already rivals Japan. Communist China is second only to the United States in producing salt. Phosphate resources are extensive and sulfur-bearing ores show promise. Fair-sized chemical and fertilizer industries are in the making. Nonmetallics like asbestos, mica, graphite, and barite are adequate. Although petroleum, copper, and aluminum are currently in short supply, these industries are likely to become medium-sized by world standards. Communist China has the mineral potential to become a first rank industrial power, but its ability in organization and technicial management remains unproved and its future per capita output probably will remain below European levels.

INDUSTRIAL MINERALS DIVISION

Cement, Lime, and Gypsum

Concrete Technology In the U.S.S.R. by *James D. Piper*—James D. Piper presents observations on precast and prestressed concrete technology in the U.S.S.R. emanating from an inspection trip to that country in May, 1958, as a member of a six-man American delegation.

He covers the subjects of concrete research, design, and construction, inspection of plants and conferences with Soviet officials and engineers.

The most important Russian organizations for testing construction practices are the Institute of Concrete and Reinforced Concrete and The Central Institute of Structures. They direct research activities on construction materials and methods.

The Moscow Design Institute and the Design Bureau of Leningrad deal with design problems and set construction standards for metropolitan areas in the Soviet Union and satellite countries. Eighty-five pct of concrete construction in the city of Moscow has been standardized.

Five factories for precasting and prestressing concrete are discussed from the standpoints of plant layout and production methods. A high degree of standardization is found to exist in the finished products, although production methods vary greatly from one factory to another.

Typical apartments are of precast concrete, and are being constructed at a rapid rate. Even radiators are made of precast elements. A precasting factory under construction is described, and a combination auto and rapid transit bridge of prestressed-precast concrete 4 000 ft in length.

Questions and facts exchanged in daily conferences, and during a visit to the Academy of Construction and Architecture in Moscow are discussed. The Soviet hosts were very interested in American techniques, and proved willing to answer fully questions concerning their own operations.

A detailed report on this subject has been published by the delegation and is available from members of the group and the Portland Cement Association.

The Role of Gypsum in Portland Cement by *Warren H. Weiss*—The major role that gypsum fulfills in portland cement concrete is to regulate the important property of time of setting. The chemical factors affecting the setting of portland cement and the effects of calcium sulphate in the form of gypsum, hemihydrate, anhydrite and soluble anhydrite are discussed. Also, the effect of gypsum upon the physical properties of portland cement paste such as: heat evolution, hydration, shrinkage, and strength characteristics is discussed.

This paper reviews briefly the present day process for manufacturing portland cement and covers the gypsum handling, storage, size, quality and quantity control as involved in the operation. The proper proportion of gypsum is fed with the portland cement clinker to the finish grinding mills. The methods used by the industry to determine and control the amount of gypsum added to obtain the optimum sulphur (SO_3) content in the finished product are discussed. A section of the paper deals with finish grinding mills, mill circuit, mill feed control, product fineness, effect of mill temperature on gypsum and side effects of gypsum on mill operation.

Use of the Coulter Counter for Particle Size Analysis of Cement by *O. E. Brown*—The measurement principle of the Coulter Counter for particle size analysis is described. The application of the Coulter Counter to cement particle content and size analyses is discussed with data developed on a number of cement samples illustrated. Potentials and limitations of this method of particle size analysis is included with methods of calibration, sample preparation and data reduction emphasized. The results of analysis are compared with other cement fineness data. The paper contains expected future uses of the Coulter Counter for particle size analysis as they pertain to research and plant control adaptations.

Application of an Automatic X-ray Spectrograph to the Cement and Mining Industries by *William R. Kiley*—The NORELCO Autrometer, an automatic X-ray spectrograph, using the Universal Detector, Automatic Crystal Changer and Electronic Discrimination is described for various applications in the cement and mining industries.

Sample preparation techniques as well as analytical techniques are discussed and evaluated.

Data on typical analytical problems of the industries are given.

Ceramic Raw Materials

Inorganic Materials Research in the U.S.S.R. by *W. G. Lawrence*—A summary of research areas on inorganic materials is presented, based on the available translated literature.

Lithium in the Ceramic Industry by *Robert J. Longenecker*—The general properties of lithia in the ceramic industry have been known for many years. Recent research and development has evolved many outstanding values which lithia contributes to ceramic systems. Not so long ago lithium mineral and compounds were thought to be rare and costly. Unparalleled activity by the industry, prompted by government demand, in exploration, mine development, process improvement and applicational research has provided, in advance of the need, the resources, processes and productive capacity to satisfy the rapidly growing demand. The growth in consumption of lithium chemicals and minerals in the ceramic industry is charted. Spodumene mining, beneficiation and projected use in the glass industry is discussed.

Applications of Lanthanon Oxides and Other Compounds in Ceramics by *G. L. Ploetz and A. T. Muccigrosso*—The various applications for the lanthanons in glasses, glazes, porcelain enamels, abrasives, refractories, electronic ceramics, and nuclear ceramics are reviewed. The sources of the lanthanons are given along with the separation processes being used for their extraction. The supply and cost data for the lanthanon oxides of various purifications are included. The properties of the lanthanon oxides, carbides and borides are reviewed as well as the properties which they may be expected to contribute to ceramic, cermet, and vitreous components.

Synthetic Mullite as a Ceramic Raw Material by *Everett A. Thomas and Karl W. Smith*—Various grades of synthetic mullite have been developed in recent years to replace or supplement natural sources of mullite derived from the mullite group of minerals consisting of sillimanite, kyanite and andalusite. Raw materials and heat treating processes used in making synthetic mullite are described. Chemical and physical data are given for typical grades and crystalline structure is illustrated with photomicrographs. The use of synthetic mullite as a refractory material in the glass and metallurgical industries is discussed.

Chemical Raw Materials

Development of a Bauxite Deposit Using Dredging as the Stripping Method by *J. G. Cazort, Jr.*—The development, now in progress, of a bauxite mine in Suriname, South America, using a 24 in. cutter-suction dredge for the removal of 15 million cubic yards of overburden is discussed. The deposit is being developed by Suriname Aluminum Company, a subsidiary of Aluminum Company of America. A brief description of the dredge and its operation, as well as some of the lessons learned which will influence future dredging plans, are included.

The problems involved are unusual in that the top of the ore body lies between twenty and fifty ft below sea level, and a tidal river flowed over its center. This river is a major drainage feature of an inhabited area having very heavy seasonal rainfall. The bulk of the overburden consists of silt, soft clay and fine sand. The thickness and physical characteristics of this material eliminated stripping by more conventional methods, many of which were considered.

The preparation for dredging included diverting the river, building access roads, ordering a dredge and pipelines to satisfy the local conditions, and preparing the dredging and spoil disposal areas. Due to the presence of swamps and structurally weak soil, these preparations required extensive planning, and control in execution. Difficulties encountered in the spoil disposal area, both during the preparations and after dredging had started, resulted in several modifications of the original plans.

After dredging is finished a protective dike around the pit will be completed. The water will be pumped out and the deposit will be ready for mining. The few remaining areas of overburden will be removed as required as mining progresses.

The Phosphate Raw Materials of Tennessee by *Robert E. Hershey*—Phosphate is the fourth ranking mineral industry in Tennessee. The estimated value during 1958 was $13,000,000, representing almost two million tons of raw material.

The Tennessee Division of Geology has mapped, in detail, the phosphate-bearing horizons of the State, and these geologic maps will be available for distribution in the near future. A study of the potential of the phosphate resources is being made in conjunction with this mapping.

The "brown phosphate" ore-bodies are residual deposits of two general types, blanket deposits and concentrations along joint planes known as cutters.

Geologic studies indicate that phosphate occurs mostly as replacement of marine organisms. Sieving of phosphate "muck" shows that the phosphate is present as fossil casts down to minute sizes and unchanged in form from original limestone.

Structure during Ordovician time influenced the accumulation of phosphate. Development of present ore-bodies is directly related to phosphate content of the original limestone.

General alignment of joint type ore-obdies may be predicted from studies of the local fracture pattern. Specific locations of ore-bodies are difficult to predict.

Refractory Chrome Ore—World Survey by *John M. Warde*—Current demand and supply position both in the United States and abroad is reviewed and the future demand-supply situation is projected. The central problems emerging and main lines of action suggested to bring supply and demand in balance are discussed.

Zoning and Grade Control of Sulfur at the Tennessee Copper Co., Copperhill, Tennessee by *Owen Kingman*—The ores at Ducktown are principally iron sulfide. They furnish sulfur for sulfuric acid, the principal source of revenue for the company, and hence are a chemical raw material. About 1¼ million tons of ore are produced annually. The zoning and grade control problems are similar to those confronted at many mining properties. Eight orebodies have been found within a two square mile area. Six of these are of several million ton dimensions. Zoning within the district is evinced by high copper ores on the flanks and low copper ores in the interior. The local classification of high copper ores are those averaging in excess of 1% copper. Pyrite-pyrrhotite ratios are the reverse of the copper distribution, the larger proportion of pyrite being found in the central ores. Magnetite is also more concentrated in the central ores. Zoning is also crudely evinced within individual orebodies. Inclusions of gangue minerals exist within the veins. These have a wide range in size, in some areas exceeding the amount of sulfide. Their shapes are irregular but in general they parallel the overall vein configuration. Efforts are made to maintain a uniform production grade on both short and long term bases. Over the long term this is accomplished by planning development well ahead of production over a broad enough area that high and low copper production may be kept in balance. Uniform daily sulfur production grade is achieved by operating several stoping areas per mine by scheduling production keeping probable grade fluctuations in mind. Additional efforts to minimize short term, daily or semi-daily grade fluctuations are exerted at the flotation mill where four large bins are filled and extracted according to a schedule that promotes mixing of the ore.

Hydraulic Fracturing of Bedded Salt by *Charles H. Jacoby*—Methods of brining salt and creating a cavity have not changed much over the last 50 years until the recent application of the principles of hydraulic fracturing to bedded salt deposits. The fracturing or splitting of beds and their subsequent uplift has allowed the brining industry to split the salt bed near its base to a target. Since this splitting was done with fresh water, a cavity was created rapidly and after the target was intersected.

The selection of the point of pressure application is one of the most critical factors of fracturing salt, as this point must correlate with a statigraphically identical point as the target. We accomplish this correlation by coring the salt strata. It is our belief that where salt beds are somewhat distorted or erratic, coring is necessary. The application of a splitting pressure and the confinement of that pressure to a specific point within the salt strata, is a factor of equal importance as correlation of the point of application and the target intersection.

It is particularly important to keep the fracturing fluid away from the bedding contact and the underlying rock due to the higher permeabilities of these rocks. Thus, it is necessary for us to plug our core hole back into the salt with an expanding cement. The top of this plug is usually the bottom of the fracture point or zone.

Then it is a matter of installing the casing in such a manner as to prevent vertical circulation of the pressurized fluid.

Trends in Production and Use of Magnesium Ores and Compounds by *Hazel B. Comstock*—The history of progress in production and use of magnesium ore and compounds is closely woven into the pattern of progress in development of such essential industries as metals, chemicals, rubber and glass. Magnesium constitutes 2.5 pct of the lithosphere and is the sixth most plentiful element. It is a chemically active metal which unites readily with many other elements. Although there are about 60 magnesium-bearing minerals the principal magnesium ores are magnesite, brucite, dolomite, and olivine. These are widely distributed over the earth. The virtually inexhaustible supply of magnesium chloride and magnesium sulfate in sea water that can be readily extracted, is further assurance of increased supplies for the continually rising demand for magnesium compounds. The principal magnesium compounds now in use are magnesium oxide, magnesium chloride, magnesium hydroxide, magnesium sulfate, and precipitated magnesium carbonate. Magnesium oxide is the principal product of the magnesium compounds industry. Its use in basic refractories has almost doubled in the past 10 years. Last year, steel producers announced acceptance of the all-basic hearth, stating that it permitted faster charging and firing rates in the furnace, which resulted in increased steel production.

Fillers, Fibers, and Pigments

A Study of the Abrasive Action of Fine Powders by *L. E. Weymouth, F. L. Kadey, Jr., and F. B. Hutto, Jr.*—The behavior of nonmetallic materials in moving contact with smooth surfaces is of interest and concern to manufacturers of abrasives, fillers, and pigments alike. The hardness, the particle size distribution, and the particulate structure of several typical abrasive materials were examined. An attempt was made to study the independent contribution of each of these factors to the abrasion of several typical surfaces. Microscopic techniques were used to evaluate the relationships among these variables.

Results with the described technique were critically compared with previous work; and the limitations of Moh's scale when applied to powdered abrasives were pointed out. Surfaces studied include silver, copper, brass, stainless steel, and several different types of finish surfaces. The new technique was correlated with and supplemented by the Valley Iron abrasion data, indentation tests, and with the polish comparator, a device developed at the Johns-Manville Research Center for comparing the polishing efficiency of different polish preparations. (158)

Some Beneficiation Techniques Applicable to Mineral Fillers by *Donald R. Irving*—Although beneficiation of nonmetallic minerals has been universally practiced, few studies have been directed towards the development of methods to upgrade mineral fillers for high-quality uses such as paint, paper, and similar uses. As the demand for mineral fillers increases as a result of expanding population, a constantly rising standard of living, and depletion of the higher-grade deposits, methods of beneficiating presently unusable materials will be required.

The Bureau of Mines, in cooperation with industry, is studying ways to improve the properties of submarginal fine clays by removing quarts, pyrite, and other impurities, and to increase the proportion of high-quality paper coater clay in Georgia kaolins by fine grinding. On the basis of research on beneficiation of clay deposits in Washington and Idaho, a plant was built at Bovill, Idaho to produce paper clay and glass sand.

The results of this recent beneficiation work by the Bureau of Mines are described briefly.

Nonmetallic Mineral Fillers in Plastics by *Robert D. Thomson*—A variety of organic and inorganic materials are used by the plastics industry as fillers. Organic fillers are derived from cellulose-containing materials, such as wood flour, cotton flock, and nutshell flours, while inorganic fillers are mostly nonmetallic minerals. Asbestos, mica, diatomaceous earth, wollastonite, and kaolin are the most widely used nonmetallic mineral fillers. They lower the cost and decrease the shrinkage of the molding compounds and, in addition, offer greater resistance to heat, chemicals, and electrical stresses. No one filler is satisfactory for all products; therefore, mineral fillers are used basically for special purposes.

Industrial Waters

Water: Industrial Mineral—and Industrial Nuisance by *Raphael G. Kazmann*—Water is not only a key industrial mineral in its own right, but in addition its presence constitutes the most important single operational problem encountered in the production of other minerals. This dual role tends to create difficulties: laws designed to foster the beneficial use of water may simultaneously create problems where water is a by-product that must be pumped to waste. As the population increases, and with it the pressure to develop and use our mineral resources more effectively, these conflicts can be expected to become more widespread and more serious.

Part of the difficulty is due to the assumptions involved in water law. Part is due to the assumptions underlying our existing mining laws. And part can be attributed to the fact that insufficient consideration has been devoted to thinking through a general, unified approach to the development of mineral resources.

Three cases are examined in some detail which illustrate the nature of the conflict between the production of water and the production of other minerals. Suggestions are made for resolving such conflicts from the standpoint of conservation.

The Cost of Converted Water by *W. Sherman Gillam*—A need for new supplies of fresh water exists today and in many specific areas that need is urgent. One solution to this pressing situation lies in saline water conversion, a most difficult problem because it must be accomplished at very low cost. Fresh water is hard to win because of the very properties that make it worth winning. The principles involved, the status of development and the estimated costs (present and future) of several conversion processes, e.g. distillation, electrodialysis, and freezing, are presented. In general, the costs presented are based on a standardized procedure for estimating conversion costs, permitting a valid comparison among the various processes.

Although theoretically possible, it is unrealistic to believe that sea water conversion methods currently under investigation or yet to be devised can produce fresh water for less than 20-25¢/1000 gals. if all costs are calculated.* Cost estimates ranged up to $5/1000 gals. in 1951. More recently, improved processes and equipment have reduced the cost of conversion to around $2/1000 gals. Further improvements in certain distillation and freezing methods (pilot plants are in operation) appear to justify a projected cost of $1/1000 gals. Similarly, improved membranes and better equipment have reduced the cost of demineralizing brackish water by electrodialysis. Depending on the salt content and other factors, the cost of demineralizing brackish waters is less than $1/1000 gals.

* According to OSW's standardized procedure.

Development of Extreme Settings on Deep Well Turbine Pumps by *Claude E. Wykes*—Deep well turbine pumps receive constantly increasing application to the problem of mining water and other fluids from great depths. Many installations of medium settings are presently operating successfully and it is felt that much greater depths are immediately within reach. Settings and lifts in excess of 2000 ft are not at all out of reason with present knowledge, experience, and materials; however, conditions of individual application will govern in each case and dictate methods and possibilities to the designer.

Design and operating problems of deep set turbine pumps are discussed together with a description of various types of equipment falling within this category.

Underground Gas Storage Effects on Underground Waters by *Douglas Ball*—Most underground gas storages are simply bubbles of gas in structural traps in aquifers. Those entirely man made—where no producible hydrocarbon existed before—change the fluid contents and pressures of the containing aquifers the most and particularly during their years of growth, but the changes are only local and short lived. Impermeable strata between aquifers sometimes apparently transmit pressure changes (much attenuated) from one aquifer to the other but these effects are even smaller and more local.

The common hydrocarbon gases dissolve in water about as readily as the gases of air, and a ring of gas in solution can be expected to surround each storage bubble. Diffusion and the flow of water or brine through the aquifer may move some of the dissolved gas away from the storage, but these effects are ordinarily small enough to be unimportant to the use of the aquifer for water supply or storage.

Use and Evaluation of Water for the Copper Mining Industry by *S. D. Michaelson*—The copper mining industry must have water to mine, concentrate and smelt its ores. Because of this, water is a vital mineral resource for the industry.

The Southwestern United States is the major domestic copper producing area. This paper discusses the use and economic value of water in only the Southwestern United States because the water supply in other copper producing regions of the country is relatively plentiful.

Typical water requirements for copper mining, milling, leaching and smelting are presented. The effect on copper recovery from variations in the quality of natural occurring waters, reclaimed waters is discussed. Primary and secondary water sources are studied and the relative cost data analyzed.

The paper presents an evaluation of the use of water by copper mining and other industries in the same area and compares the dollar yield of their products per unit of water consumed. This permits the establishment of relative value ratings for water usage.

Mineral Aggregates and Dimension Stone

Developments and Research in the Sawing of Dimension Stone by *Frank D. Hoyt* and *Howard L. Hartman*—The development of new processes and methods by The Pennsylvania State University to improve slate quarrying technology has centered in recent years on cutting and sawing stone in the quarry to eliminate a second sawing process in the mill. Two machines exhibit promise for this work: 1) a circular saw mounting diamonds or hard inserts to produce smaller sizes of stone and 2) a chain saw with insert cutting teeth to produce stone in the larger dimensions. Prototype machines have been constructed and tested in several Pennsylvania slate quarries, and one commercial installation operated for several months with a circular diamond saw. Other kinds of dimension stone may be cut by these saws.

Research at Penn State has been begun to study the fundamental cutting action of rotary tools or saws in slate and other dimension stones. A laboratory drill press is being instrumented to permit thrust-torque-rotational speed vs. penetration rate studies of single tooth cutting surfaces on stone. Machinability studies of slate conducted with tungsten carbide inserts have been performed.

Quarried Stone Meets the Challenges of Contemporary Architecture by *Ariand R. Krueger*—How new methods of quarrying and fabricating natural stone has enabled the industry to meet the demands of today's architecture. For example: New colors and textures; new patterns and designs; thin wall construction; modular sizes; new methods of installation; protection against atomic fallout; heat loss economies; air conditioning economies; durability and low maintenance; LOW, LOW COST.

Progress Report on the Beneficiation of Aggregates by Heavy Media Separation by *D. W. Jenkinson*—To meet increased cost requirements of heavy construction, concrete mixes are being refined everyday. The depletion of natural aggregate deposits within economic distance of the jobs has made it necessary to use marginal and sub-marginal sources. To meet the quality requirements of the concrete mixes beneficiation methods are fast becoming an essential part of aggregate preparation. Among the recent projects which have required application of heavy media separation are: Vandenberg Air Force Base, Glen Canyon Dam, Flaming Gorge Dam, South Saskatchewan Dam. Improvements in the processes used, metallurgical results, mechanical modifications are presented in this progress report.

Factors Influencing the Establishment of a Clay Lightweight Aggregate Plant by *Stanley A. Feitler*—The manufacture of lightweight aggregate for structural uses has grown rapidly during the past 10 years and continued growth is anticipated. To reduce risks involved in establishing a new plant, a thorough preliminary investigation is necessary. This paper outlines and interrelates some of the factors on which a successful operation depends.

Favorable location with respect to an adequate market is a primary factor. Two general processes, one using a kiln and the other a sintering machine, are currently used in making lightweight aggregate from clay, shale, or slate. The choice of process depends on the characteristics of the raw material which in turn should be chosen for its location with respect to a chosen market area.

Lightweight Clay Block Using Vermiculite by *Gilbert C. Robinson*—There is considerable interest in the ceramic industry in producing fired structural block made from mixtures of clay and various aggregates. The block would have the shape of concrete block and meet the product specifications for concrete units. The fired clay block would weigh only 20 pounds.

The different manufacturing methods and aggregates employed are discussed with particular emphasis on the pilot plant production of block using vermiculite as the aggregate material.

Rare and Radioactive Minerals

Non-Pegmatitic Deposits of Beryllium in the United States by *W. R. Griffitts*—Beryllium-bearing pegmatites are known to occur in most areas of high-rank metamorphic rocks in the United States, though there are marked regional variations in the abundance of beryllium minerals in them. Beryllium minerals are especially abundant in the pegmatites of South Dakota, the southern Rocky Mountains, and parts of New England; they are rather scarce in Montana and the large pegmatite districts of the Southeast.

Non-pegmatitic deposits of beryllium minerals or of beryllium-rich rock are not generally associated with beryllium-bearing pegmatites. Non-pegmatitic veins and beryllium-bearing tactites are particularly widespread in the Basin and Range Province. The small number elsewhere includes the beryl vein at the Boomer mine in Central Colorado. The common high beryllium content of residual manganese ores of the Southern Appalachians contrasts curiously with the relatively small amount of beryllium in the pegmatites of the region and with the low beryllium content of most western ores. Few other metal ores contain much beryllium.

Pegmatites and Their Mineralization in the Storm Mountain Area, Larimer County, Colo. by *Margaret Fuller Boos*—Pre-Cambrian granitic pegmatites on the west, southwest, south, and southeast slopes of Storm Mountain, Larimer County, northern Colorado, were explored and mapped geologically 1956-59. The area between Crystal Mountain Mining District on the north and Hyatt pegmatite mine area on the south was nearly inaccessible until a company built an access road, which was completed in 1939, into the Roosevelt National Forest. The jeep-type forest roads were also used, then.

The area is extremely rugged, rising from some 6,000 ft altitude on the highway at Drake on Big Thompson River, to over 10,000 feet at the summit ridge of Storm Mountain.

Almost innumerable pegmatites of every possible type of granitic pegmatite intrusion infest the Pre-Cambrian gneisses and schist of the east-southwest tilted fault block of Storm Mountain. The major bodies trend northeast-southwest and stand 100 to 200 ft high above the surrounding forest floor. They are known to extend to at least 200 ft below the surface and to blunt out at the southwest or be faulted out. Strike length is 200 to 600 ft. Contents are locally zoned and show commercial bodies of beryl-potash, feldspar, mica, uranium minerals, and quartz.

Evaluation and Marketing of Rare Earth Deposits, Ores and Concentrates by *Judson H. Whitman*—Among mining men, from the prospector through the highly trained geologist and engineer, there is a definite lack of knowledge as to what may constitute a potential commercial rare earth property. Value of such a property depends primarily on the rare earth elements and minerals present, associated gangue minerals, grade of the ore, tonnage available, amenability to separation and purification.

The requirements of the various processors vary considerably, depending upon the process which they may use and the particular elements which they may be needing. Generally the processors may be divided into two classes; those working with the "heavy" or yttrium group rare earths, and those working with the "light" or cerium group. Some companies may process both groups.

Each processor tends to have its own specifications for raw materials but such specifications may be considerably modified by economic factors and availability. Evaluation of any property is dependent primarily upon these factors.

Niobium at Powderhorn, Colorado by *Robert M. Grogan*—The niobium mineral, pyrochlore, has been found in carbonatite bodies in the alkalic rock complex at Powderhorn, Colorado, thirty miles southwest of Gunnison. It occurs as gray to brown octahedral crystals, mostly less than 2 mm in size, widely distributed in narrow planar zones. It is generally accompanied by apatite and magnetite, all three being considered late primary minerals. The amount of Nb_2O_5 present in the pyrochlore is probably in excess of 100,000 tons.

The carbonatite bodies comprise a stock and numerous dikes of substantially identical composition and presumed common magmatic origin. The stock forms Iron Hill, 900 ft high and approximately 1.5 square miles in area. The dikes are numerous close to the stock, where they intrude pyroxenite, and become less abundant with increasing distance from it. Dikes have been observed in the fenites which form the rim of the Powderhorn complex and in the surrounding pre-Cambrian gneisses and schists at distances of several miles from Iron Hill.

In addition to niobium, the carbonatite bodies also contain minor amounts of rare earths and thorium. Cerium group metals are present in variable amounts in the apatite and the presence of bastnaesite, cerite, and synchisite has been reported by other investigators. Thorium occurs in the pyrochlore and probably in other minerals as yet unidentified. Radioactivity attributed to thorium has been noted in many exposures of carbonate.

The Gamma Ray-Neutron Beryllium Detector as a Reconnaissance Tool by *Louis Moyd and Pauline Moyd*—A commercially available portable detector was used in a field and laboratory survey of geologically favorable environments for deposits of beryllium throughout the U.S. and Canada, including aplites and pegmatites, alkaline complexes, veins, greisens, tactites, and skarns.

The detector is completely selective for beryllium, "Hard" gamma rays given off by $Antimony^{124}$ convert the normal $Beryllium^9$ to $Beryllium^8$, releasing a neutron. Neutrons are counted by a scintillator circuit designed to favor neutron responses while suppressing those of gamma rays.

The instrument weight about 30 pounds. Laboratory and field mounts were built to facilitate handling and to minimize radiation exposures. A bench-top arrangement permitted rapid scanning of trays of specimens and drill cores. A litter-type rig was carried by two people for examination of outcrops, underground workings, and dumps. Radiation dosages were well below recommended limits.

Major Advantages:

1. Detects and delineates beryllium mineralization in any form, even disseminations of microscopic grains of obscure minerals.
2. Proves absence of beryllium from occurrences in which it was erroneously reported, generally on the basis of faulty analyses.
3. Provides rough quantitative analyses immediately, in the field.

Major Disadvantages

1. Radioactive source necessitates special training and licensing.
2. Source is self-consuming, requiring periodic replacement.
3. Effective "terrane clearance" is less than one inch, necessitating static tests rather than continuous scanning of exposures.
4. Too heavy and bulky to be carried regularly on routine reconnaissance.

Illustrations will show the detector in use in the field. An instrument will be available and its response to various types of beryllium ores will be demonstrated.

MINERALS BENEFICIATION DIVISION

Chemical Processing

Commercial Separation of the Heavy Rare Earths by Ion Exchange by *J. R. Gump*—The heavy rare earths were first separated by fractional precipitation and crystallization. In recent years, however, the method of ion exchange has been used for the separation and it is possible to prepare highly purified oxides and salts of the rare earth elements by employing this process. By the use of cation exchange resins in large columns, it has been possible for Michigan Chemical Corporation to produce tons of high-purity rare earth oxides. The production of these rare earths includes the employment of ethylenediaminetetraacetic acid at a regulated pH as the eluting agent and the application of copper ion as the retaining ion for the front of the ion exchange resin band. A discussion will be given of the procedure required for the separation of the rare earths including the feed, the number of band lengths, the lengths of bands, the pH control, the concentration of eluant EDTA, and the purity of product. A description of the separation of the scarce heavy rare earths, such as thulium and lutetium, also will be presented. A comparison of present prices of pure rare earth oxides with prices of only a few years back will be set forth to show the decreases made since the use of large-scale ion exchange equipment for the separation of rare earths. The future of the heavy rare earth industry holds much promise.

The Recovery of Molybdenum by Liquid-Liquid Extraction from Uranium Mill Circuits by *C. J. Lewis and J. E. House*—Molybdenum in uranium pregnant solutions may give rise to processing problems. These are usually controlled by the use of the "bleed stream" technique. Where applicable in acid leach circuits using solvent extraction, a portion of the recycling organic phase is usually scrubbed with sodium carbonate to remove the molybdenum which is then wasted. When necessary in the alkaline leach circuit, a portion of the recycling alkaline leach liquor is discarded, in order to hold molybdenum or other impurities within acceptable limits.

A quaternary ammonium salt, Aliquat 336, offers promise as an extraction reagent for the economic recovery of molybdenum now wasted as just explained.

Amine extraction reagents presently used by the uranium milling industry are effective only in acid media; whereas, the quaternary ammonium salt, Aliquat 336, is, under some conditions, an efficient extraction reagent for molybdenum not only in acid media, but also in alkaline media to a pH value as high as pH 10.0. The ability of this reagent to extract molybdenum in weakly acidic or alkaline media considerably improves the economics of molybdenum recovery from uranium mill circuits.

Data arising from the use of Aliquat 336 to recover molybdenum from uranium mill circuits is presented and discussed. Flowsheets are described for the recovery of molybdenum from both sulfuric acid leach and alkaline leach uranium mill circuits. A preliminary evaluation of the economics of molybdenum recovery using Aliquat 336 is offered.

Application of Continuous Filtration to Precipitate Dewatering by *R. C. Emmett and D. A. Dahlstrom*—The application of disc and drum type filters to the dewatering of mineral concentrates has been practiced for many years. With the advent of chemical extractive metallurgy, filtration of chemical precipitates has become imperative to good operation in many processes. In the majority of applications, relatively non-granular solids must be handled and in many of them, high purity specification in the dewatered product must be maintained. These two factors predominate in the selection and design of the filter station.

The paper discusses the various types of continuous filters employed for precipitate dewatering with particular emphasis upon specific advantages for each general application and filter cake discharge methods. Bench scale test and correlation methods for determining type, capacity and predicted full scale results are also given. The influence of product purity requirements on filter type and design is also discussed. Selection of filter media to improve cake discharge, resist blinding and increase cloth life is stressed. Filter station design with auxiliary processing equipment to facilitate ease of operation, increase recovery and minimize overall operating costs is emphasized.

A Study of Oxidation and Cyanide as an Oxidation Catalyst in Pressure Leaching of Uranium by *D. C. McLean and Victor E. Padilla*—In plant studies at Homestake-Sapin Partners New Mexico Mill it has been indicated that sodium ferrocyanide is an effective oxidant in alkaline uranium pulps. Evidence that the oxygen consumption by a particular ore is more important than the O_2 partial pressure in pressure leaching led to staggered additions of air with catalytic type oxidants for optimum results. Air dispersion is a prime factor in the oxidation of uranium for maximum extraction.

Comminution Symposium

Prediction of the Size Distribution Shift in Grinding by *G. Agar and R. J. Charles*—It has been previously reported that the manner in which a product size distribution curve shifts to finer sizes with continued grinding is experimentally related to the dispersion coefficient of the size distribution. Recent work, based on the mechanics by which particles in a mill are fractured, indicates that the above relationship is not accidental but should be expected. The present work illustrates a number of cases in which the above effect is observed.

Kinetics of Comminution by *Nathaniel Arbiter and Upendra N. Bhrany*—A comprehensive study has been made of the rates of information of the various screen size fractions in ball mill grinding. To a close approximation, the initial rates of production are constant for all screen sizes, with the period of constancy increasing progressively with decreasing particle size. The initial rates of formation vary exponentially with screen size. The exponent depends on the material and, to some extent, on the conditions of grinding. It is shown that this exponent and the exponent in the Schumann weight versus size equation, are the same. And further, that the Schumann equation is valid only for those size fractions, and during those time intervals, involving constant rates of production. Where the rates of formation follow first order kinetics, it is shown that a Rosin-Rammler type equation obtains.

The variability of the exponent in the rate constant versus size relationship, and the related weight versus size relationship, lead directly to the disproof of the so-called grinding laws of Kick, Rittinger, and Bond. The kinetic concepts are shown to apply to three sizes of batch ball mills, and to a small continuous rod mill.

Energy-Size Reduction Relationship for the Grinding of Quartz by *J. H. Brown, S. R. Mitchell, and M. Weissman*—Samples of quartz were ground in a laboratory ball mill for periods which ranged from 5 minutes to 700 hours and the energy-size reduction relationship for this comminution operation was evaluated. The results conformed to a relationship such as suggested by Charles over a major portion of the grinding period. At extremely long grinding times, the product approached a limiting particle size of the order of a few hundred angstrom units.

Retention Time in Continuous Vibratory Ball Milling by *D. W. Fuerstenau*—The variable hypothesis of Charles and Holmes can be extended to continuous grinding through the use of retention time as a measure of the energy expended on a material during comminution. This was verified experimentally by grinding chromite in a continuous, open-circuit vibratory ball mill. For continuous grinding, a statement of the grindability of an ore must include a factor which determines the fraction of the total energy which is being utilized for grinding. This factor depends upon the weight of material retained in the mill at steady state.

Energy Input and Size Distribution in Comminution by *R. Schuhmann, Jr.*—When the distribution of material in the fine sizes of a comminution product can be represented by the empirical equation, $y = 100\left(\frac{x}{k}\right)^{\alpha}$, it is shown that the energy input is given by $E = AK^{-\alpha}$ and that the same constants k and α are involved in both the size distribution equation and the energy equation. These derivations support a basic and very practical definition of grindability $\left(\frac{1}{A}\right)$ as the quantity of comminuted materials finer than unit size produced per unit of energy expended. Finally, it is pointed out that the hypotheses of Kick, Rittinger, and Bond all work equally well in calculating theoretical energy requirements from size distribution data, so that there is no point in attempting to give a special significance to any one of these hypotheses.

Energy-Size Reduction Relationships at Fracture for Single Particles by *Bert Bergstrom, C. L. Sollenberger, and Will Mitchell, Jr.*—A unique compression testing machine was constructed to load individual ⅛ to 1 inch spheres of glass, etc., at rates from 100 to

100,000 pounds per minute. During loading the applied load was continuously plotted versus the deformation of the sphere-platen system. The load-deformation curve conforms to the theory of elasticity. The spheres were surrounded by steel retaining rings or by gelatin (to prevent secondary fracture). The product size modulus was determined from screen analyses.

The data shows: 1) Energy input per unit mass is inversely proportional to the product size modulus (or directly proportional to the surface area per unit mass). 2) Increased loading rates slightly increase the energy input per unit mass required for fracture without affecting the preceding relationship. 3) Average energy input per unit mass required for fracture is inversely proportional to the 4/3 power of the sphere diameter for glass (amorphous), inversely proportional to the 2/3 power of the diameter for sapphire (single crystals loaded along "C" axis), inversely proportional to the diameter for quartz (polycrystalline).

Theory and experiments show that much of the input strain energy is transformed into kinetic energy of fragments at fracture, this being the reason efficiencies based on "surface energies" are exceedingly small. This large kinetic energy component is usually dissipated as heat but may be partially reclaimed because impact of fragments against the surface of steel retaining rings causes additional comminution.

Theory of Fracture and Comminution of Brittle Solids by *J. J. Gilvarry*—The theory of probability is used to calculate the distribution function for fragment sizes in *single* fracture (i.e. not repetitively produced by a mill). On the model adopted, fracture planes are initiated at Griffith flaws on the surfaces and edges of fragments. When the effect of edge flaws is predominant, one obtains the Rosin-Rammler and Schuhmann equations as limiting forms. Depletion factors are introduced into the distribution function by means of the theory of probability, to take account of the fact that the number of Griffith flaws in a specimen is finite for single fracture. The resulting distribution function lies above the Schuhmann line in the coarse sizes and below it in the fine sizes. In the latter region, the function approaches zero at a rate yielding convergent integrals over the distribution for physical quantities such as the total surface, without the introduction of a non-vanishing lower limit on particle size. The modifications in the distribution function corresponding to grinding in a mill are discussed. Confirmatory experimental data are presented.

Concentration

Development of a New Dry Method for Mineral Separation by *R. J. Brison and O. F. Tangel*—A new method has been developed for the removal of impurities from rock salt. This method consists of selective heating of the impure particles by radiant heat followed by separation on a belt coated with a thermoplastic resin. The heated particles adhere to the resin and are rejected. Although the method was developed specifically for rock salt, it is believed that variations of the method will be applicable to a number of other separation problems.

Beneficiation of Rock Salt at the Detroit Mine of International Salt Company by *W. C. Bleimeister and R. J. Brison*—The first commercial plant for beneficiation of rock salt by a new method has been installed in the Detroit Mine of International Salt Company. The plant employs a dry process consisting basically of selective heating of the impurities by radiant heat followed by separation on a belt coated with a heat-sensitive resin. The plant, which has been in operation since 1957, has a capacity of 35 tons per hour of rock salt in the size range from ¼ inch to ⅜ inch.

The Copper Segregation Process by *Carl Rampacek and W. A. McKinney*—The treatment of oxidized and mixed oxide-sulfide copper ores by the segregation process is discussed, and the results of laboratory batch and small scale continuous tests by two different procedures are presented. The segregation process comprises heating the crushed ore with salt and coke or other carbonaceous materials at about 750°C to produce fine metallic copper, which is recovered by conventional flotation methods. Applicability of the process to ores containing silver, gold and other metal constituents, together with some laboratory test data, also is discussed.

Magnetic Recovery of Germanium Sulphide with the Frantz Ferrofilter by *M. A. Bouchat, A. Detiege, and D. Robert*—The purpose of this paper is to describe a new process that has been developed to produce high Germanium Concentrate from African ore. In 1956, the Union Minière du Haut-Katanga selected new techniques of recovering Renierite from copper concentrates, which are obtained by flotation in the "Mine Prince Leopold" concentrator at Kipushi (Belgian Congo). Renierite is a mineral with As, S, Cu, Fe, Zn and Ge among its principal constituents. The recovery is carried out by wet magnetic concentration through Frantz 461 type ferrofilters. This process yields concentrates containing from 0,3 to 1,5 pct Ge and recoveries varying between 10 and 30 pct. Investigations showed that there is no relation between the grade of the concentrate and the recoveries. This can be explained by the lack of relation between the Germanium grade of the concentrate supplied to the ferro-filters and the ratio of free Renierite present in this concentrate. We also describe the physical, chemical and particularly the magnetic properties of Renierite which vary greatly from those of Tsumeb Germanite. Preliminary experiments were undertaken, on a laboratory scale, with a 31 type ferrofilter. This work was extended to a 461 type ferrofilter, and finally plant investigations were conducted and worked out with twelve automatically controlled 461 ferrofilters.

Magnetic Roasting of Iron Ores

Magnetic Roasting of Iron Ores in a Traveling Grate Roaster by *Henry H. Wade and Norman F. Schulz*—An experimental traveling grate roaster having a proven capacity of 1000 pounds of dry ore per hour, and up to 4000 pounds per hour under special conditions, has been built and operated at the Mines Experiment Station of the University of Minnesota. The heat and the reducing atmosphere required in the process are produced simultaneously in a burner designed as an integral part of the apparatus from a mixture of natural gas and air. Various low grade iron ores are crushed to ⅜ inch or less, agglomerated with water in a balling disc, and their iron contents successfully converted to magnetite in this equipment.

The Magnetic Reduction of Jaspilite in a Shaft Furnace by *J. R. J. Edwards and S. G. Salamy*—Factors governing the selection of a tandem shaft furnace for magnetic reduction of a dense, low grade hematite iron ore, jaspilite, are discussed.

The pilot plant operation of a 1.5 ton per hour tandem shaft furnace is presented. Special reference is made to the influence of temperature on the rate of reduction and on the grade of concentrate produced by subsequent grinding and Davis Tube magnetic separation. It was found that optimum results, with respect to both rate of reduction and concentrate grade, were obtained when the reduction temperature was 600°C.

Mechanism of Magnetizing Roasting of Iron Ores by *J. E. Astier, P. Emery, and A. Matraski*—An explanation of some of the fundamental mechanisms in the reduction of iron ores, with reference to the diagram by Chaudron. Presents data on the influence of SiO_2 on equilibria between the various iron oxides and metallic iron, and a diagram showing the equilibria for a system of SiO_2 and iron oxides in which fayalite is taken into account.

In magnetizing roasting tests on pure hematite ore, low grade minette ores (from Lorraine), and especially on chloritic iron ores, it is seen that reduction of iron oxides proceeds farther than the magnetite stage even if the composition of reducing gas is chosen in accordance with the classical Chaudron diagram so as to be oxidizing towards wustite.

The Reaction of Low Grade Non Magnetic Iron Ores to Magnetic Roasting in a Fixed Bed by *W. H. Dailey, Jr. and F. H. Bunge*—A Laboratory batch magnetic roaster with a fixed bed was built for experimental magnetic roasting studies. Roasting studies on a number of low grade rock samples and on balled crushed or ground ores was completed. The studies were made with cracked propane for the reduction gas. Precise control of gas composition, gas flow, temperature, and reduction time were maintained in the study. Updraft and downdraft drying of balled charge were also investigated.

Development of Beneficiation Technology for Hematite Ores by *N. P. Titkov*—The report on "Development of Beneficiation Technology for Hematite Ores" presents the results of experimental and pilot plant investigations in an effort to develop a rational method for beneficiating the hematite ore varieties from the Krivoy Rog, the Kurek Magnetic Anomaly, Olenogorsk, and other deposits. These ores were subjected to beneficiation by gravity, magnetic (in a strong field), flotation, and magnetizing roast methods. Rational beneficiation methods, depending on the mineralogical composition of the ore and impregnations of metallic and non-metallic minerals, were developed.

The report points up the dependence of the technological indexes of the various beneficiation methods on the iron silicates and quartz content of the ore.

From the results of these investigations and from technical economic computations based on the cost of one ton pig iron smelted from concentrates which were obtained by the various beneficiation methods it was established that:

1. When the hematite ore impregnations are not uniform it is advisable to use a gravity-flotation method. Ore with a particle size of up to 50 mm is beneficiated by gravity (gravity suspensions, jigging and concentration) for the purpose of separating a lump concentrate. With some types of ore the tailings (waste product) are separated as well. The middlings from the gravity method are subjected to further diminution and flotation.
2. Finely impregnated hematite ores containing small quantities (not more than 4-5%) of iron silicates are most effectively and expediently beneficiated by flotation. Anion as well as cation collectors may be used. Of the anion collectors it is advisable to use the harmless collectors—sulfate soap, tallel emulsion with various froth depressors.

Investigations showed that the water may be recirculated after precipitation of the solid phase. Depending on the mineralogical and chemical composition, flotation of these ores will yield concentrates containing up to 65% Fe and 94% extraction.

3. Finely impregnated mixed hematite-magnetite ores may be beneficiated by a magnetic-flotation or a single flotation process.
4. Finely impregnated hematite ores containing large quantities of iron silicates and ocherous varieties are most effectively beneficiated by a magnetizing roast. With this beneficiation method, it is possible to obtain concentrates containing up to 58% Fe and a rather high extraction of up to 90%. Although preliminary magnetizing roasts are expensive, the pig iron obtained from this type of ore requiring such magnetizing roasts is least expensive.

Some Factors Influencing the Physical Qualities of Iron Ore Pellets by *K. E. Merklin and M. H. Childs*—Pellets produced from finely ground magnetite have now become a major source of iron. Research is being carried on to determine what factors influence the quality of pellets in a continuing program of product improvement. Recent studies have shed some additional light on the following points: 1) The use of coal in pelletizing, 2) The effects of concentrate surface area on green and fired pellet quality, 3) Bentonite and soda ash as additives, 4) Factors influencing thermal shock, 5) Time at temperature, and 6) Cracks in fired pellets.

Materials Handling and Mill Design

Influence and Application of Side Frame Rope Belt Conveyors to Surface Coal Handling Facilities and Preparation Plant Design by *E. Morgan Massey*—With the rapid development and acceptance of high-capacity coal extraction equipment, the cost of transporting coal from the mining faces through the cleaning process to the railroad car is the biggest item of modern mining costs.

Recently wire rope suspended belt conveyors have proved to represent a great saving over rigid belt structure in underground installation costs with less wear and tear on expensive belting by cushioning the load.

To minimize this overall transportation cost at Ben Creek #2 mine—near Gilbert, West Virginia—in removing the coal from seams high in the mountains to a screening plant located over two railroads in the narrow valley below, the coarse-coal, heavy-media plant and fine-coal, Deister plant were located at points up on a ridge above the railroad so that 30 to 40% rejects could be handled by gravity to storage on the opposite slope.

Wire rope belt conveyors were used from the hillside storage at seam levels throughout the system; the resilient mounting of each idler enabling the conveyors to handle higher capacities on greater

slopes. The catenary action of the wire rope permits the conveyors to be strung on mud sills over rough ground and greatly simplifies steel work where the conveyor is suspended on simple bar joist trusses making the complete installation a do-it-yourself job.

The low first cost and other advantages that make rope sideframe construction popular underground apply to even greater advantage for cross country greatly simplifying and reducing the overall cost of the complete materials handling system.

Intraplant Transportation and Handling of Bauxite at Suralco's Paranam, Surinams, S. A. Works by *Philip Dorrance*—Bauxite; mined, crushed, and washed on the east bank of the Suriname River is loaded by conveyor into barges; towed five miles upstream to Paranam on the opposite side of the river where it is unloaded by electric clamshells onto a conveying system feeding the drying facilities. The paper describes the loading, barging, and unloading facilities and gives performance figures for each operation. The use of two electric Bucyrus Erie 54-B excavators as clamshells with stationary turntables mounted on dock has proved to be a unique and economical choice of barge unloading equipment.

Operating Control

Basic Concepts and Automatic Control of Continuous Filtration by *D. A. Dahlstrom*—To properly automate continuous filters, a thorough understanding of the fundamentals of continuous filtration is mandatory. Automatic control will be a function of not only the variable to be controlled but even more important, the basic filter design, type of application and the rate functions occurring within the filter cycle.

With regards to basic filter design, there are two separate categories,—those picking up filter cake against gravity and those with gravity. In addition, there is the natural division between continuous pressure and continuous vacuum filtration. Individual filter operating principle also influences automatic control.

Type of application will generally predicate the factors that must be regulated to yield desirable results and additionally dictate controls that must be employed to provide proper operation on the upstream and downstream side of the filter.

The filter operation may be composed of as many as 4 rate functions,—all of which must be correctly incorporated into the filter cycle.

1. Cake formation rate
2. Cake dewatering rate
3. Cake washing rate
4. Cake thermal drying rate

Generally, the slowest rate function will be controlling but if proper time within the filter cycle is not allotted to each, results will be well below expected. This is also important with automatic control application.

The paper discusses the four basic rate functions and examples of how they are incorporated into the filter cycle. Their influence upon automatic controls is also illustrated. The effects of type of filter design and application is also shown and several examples quantitatively discussed. Special emphasis is placed upon taking full advantage of any self regulation inherent in the filter design or rate functions.

Automatic X-ray Fluorescence Analysis of Titanium in Ilmenite by *Erkki Laurila and O. Castren*—A description of equipment for automatic X-ray Fluoresence analysis of mill pulps at the Otanmaki Company plant in Finland is given. The development of the method through laboratory, pilot-plant, and commercial plant use is described. One of the more difficult problems involved in the application of any method for automatic analysis of mill pulps is the sampling of the wet product stream and processing it for analysis. The authors describe their sampling problem and methods of solution

Infrared Radiometric Methods and Their Application to Remote Temperature Measurement by *George R. Mitchell, H. L. Berman, and A. E. Goldberg*—Recent advances in infrared technology have extended the methods of radiation thermometry to much lower temperature ranges than have previously been possible. Infrared radiation is defined as that portion of the electromagnetic spectrum extending from wavelengths just greater than visible radiation and merging with the radio spectrum at submillimeter wavelengths. All objects emit electromagnetic radiation in the infrared band of the spectrum. Since the emitted radiant power is a sensitive function of temperature, a measurement of this energy will provide an accurate indication of the temperature of the emitter. This allows the determination of the temperature of an object without contacting the body with any sort of physical probe. Temperature measurement of moving objects as well as remote temperature sampling of inaccessible locations are now possible.

The function and use of the infrared radiometer for measuring radiant flux is presented along with the methods by which these measurements are related to temperatures. Applications of radiometric methods to industrial temperature measurement and temperature control are discussed. The instrumentation for accurately performing various remote temperature measurements is described.

The Mill With No Operators by *Wayne C. Hazen and S. Power Warren*—Instrumentation and automatic controls have not been applied as successfully in ore treating plants as in other parts of the chemical industry. This paper advances the hypothesis that standard minerals beneficiation equipment was designed prior to the development of modern instrumentation and is therefore not well suited for automatic instrumental control. Most modern chemical processing equipment such as in oil refineries, on the other hand, was designed with instrument operation in mind and is therefore adapted for automatic control without human operators. It is suggested that the age of automation in mineral beneficiation will come about through radical changes in the design of machinery rather than through the grafting of electronic devices on present equipment. Such changes would incorporate the use of the new discoveries in physics, chemistry and electronics.

To illustrate how such a different approach could alter the appearance of an ore treatment plant, a fanciful story is told of an inspection trip through a hypothetical uranium mill ten years from now. How such new equipment might operate is described and the basic operating principles discussed. Although the machinery described has never been designed, it is pointed out that some of the possibilities are not as far fetched as they first appear to be.

Solid-Fluid Separation

Measurement and Control of Pulp Density by *L. E. Sausa and J. E. Martinson*—The Bubble Tube Pulp Density Meter measures the specific gravity of pulps accurately, is simple to operate and requires very little maintenance.

Union Carbide Nuclear Company at Bishop, California, began search for an accurate pulp density measurement in the laboratory. After laboratory development, the density meter went into plant operation and now also controls and records pulp densities.

The design of the bubble tubes, water purging and method of sampling of flow are a few of the factors that make the instrument effective for year in, year out operation.

Automatic Thickener Control at Marmoraton Mining Company by *William M. Aubrey, Jr.*—The amount of material going to the thickener which precedes filtering is automatically controlled to maintain a certain inventory in the thickener. Excess feed is diverted to pits for storage. The amount of material removed for the thickener circuit is automatically controlled to correspond to the demand of the filters.

MINING AND EXPLORATION DIVISION

Open Pit Mining

Industrial Accident Prevention and Health by *Paul Lee Hunter*—The presentation describes the unique approach to accident prevention activities used successfully at the Chino Mines Division, Kennecott Copper Corporation. Costs as well as safety statistics for the past 10 years are revealed as justification for this approach to accident prevention.

The basic philosophy and approach towards accident prevention is developed through graphic formulas to show the effect of good supervision on production and safety.

Industrial health surveys made at this company are revealed to show the importance of fitting the employee to the job. Pre-employment physical examination procedures are discussed in an effort to illustrate the importance of selecting the best available employee from existing labor markets, especially in these economic conditions, which require management to assume complete responsibility for the health of employees and their families. Production, accident prevention, and industrial health are tied together by the concluding remarks under the title of good management.

Use of Digital Computers in the Mining Industry by *P. B. Nalle and L. W. Weeks*—Several small and medium size digital computers are now available to industry at prices starting from about $40,000.00 Most mining companies have personnel who, with suitable training and aid from machine manufacturers, can programme and operate a computer. A digital computer, by its nature, is well suited to handle two types of problems—those which are repetitive occur over and over again; and those which do not occur frequently, but are so complex as to make computer solution a necessity.

Examples of the first type of problem would be cut and fill or bench tonnage calculations; reduction of stadia notes, and the like.

The second type of problem would be statistical studies, problems in factorial designed experiments and linear programming.

The Riverside Cement Company has been using a computer to solve ore blending problems on a linear programming basis for almost a year, with good success. Some specific examples of how this method of ore blending control is used in the cement industry and how it might be used by the mining industry in general can be given. Linear programming is technique which can be applied to many varied problems. Riverside feels that they are just starting to use a valuable tool for the industry.

The Application of Explosions Research to Blasting in Mines and Quarries by *Clifton W. Livingston*—When the first atomic bomb was dropped, the status of blasting as an art rather than as a science immediately became apparent. The advice of mining people and of explosive manufacturers was sought on numerous matters requiring a knowledge of how rock fails when subject to impact or explosion. Unfortunately, the information was not available; but, fortunately, research began and was directed towards fundamentals. Evidence recently has been obtained to demonstrate that at least three types of failure occur in blasting. These are: 1) the shock type, 2) the shear type, and 3) the viscous damping type. A concept known as "the theory of relative behavior of materials" has evolved and from it the breakage process equation and principles developed. Using the breakage process equation and principles of rock mechanics, it is possible to appraise blasting practice, to determine whether or not it can be improved, and if so, how.

Portable Crusher in Open Pits and Quarries Operation by *B. J. Kochanowsky*—In certain instances, the conveyor haulage could replace the truck or track haulage in open pits and quarries operation and reduce the haulage costs. However, because of the size of material blasted, the mechanical shovel can not load it directly into the conveyor. A portable crusher is the solution. In this case the mechanical shovel would load the blasted material into the crusher. This crushed material in turn will be hauled by conveyor to the plant, where secondary crushers and screens are located.

The portable crushers have been successfully utilized in civil and military construction for many years, but is not yet used in open pits or quarries operation. Much larger crushers will be required for this purpose; however such projects are feasible and the costs could be reduced.

An analysis is made of the applicability of the portable crusher and conveyor in open pits and quarries operation.

Society of Economic Geologists

The Genesis of the Sulfide Deposits of Northern New Brunswick—An Interpretation Based on Sulfur Isotopic Studies by *W. M. Tupper, M. L. Jensen, and P. Hurley*—The two types of sulfide deposits in the Bathurst-Newcastle area are: a) epigenetic fissure deposits,

and b) massive sulfide deposits. Geological evidence has been variously interpreted to suggest a sygenetic origin, a source-bed origin, or a magmatic hydrothermal origin for the massive sulfide deposits.

Sulfides disseminated through the black shales and argillites of the host rocks are enriched in S^{32} (mean value = 22.34, S^{34} = −5.8 per mil) relative to the meteoritic standard of 22.21, and have a broad spread in range of values.

S^{32}/S^{34} ratios of sulfide minerals from the deposits occur in two distinct groups. The massive sulfide deposits exhibit ratios between 21.88 to 22.05, while the fissure deposits exhibit ratios between 22.18 to 22.21. These results suggest two separate sources for the sulfur, each however, resulting in magmatic hydrothermal deposition because of the narrow spread of ratios in each group.

Granites intrusive into the host rocks of the sulfide deposits have a mean K/A age of 386 ± 10 m.y. Lead minerals in the sulfide deposits have a mean model lead age of 370 ± 20 m.y. Thus the lead minerals and the granite bodies were emplaced during the same major orogenic era.

Sulfide minerals from one magmatic hydrothermal deposit have a very narrow range of S^{32}/S^{34} values as do those of the Bathurst area. It seems reasonable, therefore, that well homogenized magmatic hydrothermal solutions are the most logical source for the sulfide deposits. Furthermore, the homogeneity of the lead isotopic abundance data gives strong independent evidence that the ores are of a magmatic hydrothermal origin.

Mineralogy and the Question of Zoning, N.W. Illinois Zn-Pb District by *J. C. Bradbury*—A detailed study of the mineralogy and paragenesis of the deposits of the northwestern Illinois zinc-lead district has revealed evidence, both crystallographic and spectrographic, that indicates conditions of ore deposition were the same throughout the vertical ore-bearing interval. Except for an increase of galena relative to sphalerite in the upper horizons, the details of the mineralogy and paragenesis of the small, shallow "crevice" deposits and the larger, deeper "flat-and-pitch" deposits are the same. Spectographic analyses, likewise, show no differences between sphalerites from the different stratigraphic horizons. Color bands within the sphalerites show systematic differences in trace element content, with the dark-colored layers containing more Ge, Fe, and Mn and the light-colored layers containing more Cd. This color-banding, however, is typical of all the sphalerite, regardless of stratigraphic position of the orebody.

On the basis of the above evidence, there is no justification for postulating zoning, in the sense of temperature or intensity zoning, for the northwestern Illinois deposits. The vertical change in the sphalerite: galena ratio apparently is related to the sequence of deposition and the location of open spaces available for mineral deposition at any specific time during the mineralization period.

Unified Field Geology Applied to Beryllium Prospecting by *Einar C. Erickson*—Summarized by Umbgrove (1947), lineament tectonics is being brought to useful precision by Hill (1956), Lacy (1957), Wisser (1960), Erickson (1959), and especially Mayo (1958). Four dominant structural directions are recognized: E-W (A-lines), N-S (B-lines), NW-SE (C-lines), and NE-SW (D-lines), the regmatic pattern of Sonder (1947). Far from obvious, they are in places discontinuous, elsewhere inferred, but when understood and delimited precision pin-pointing of thermodynamically favorable zones for mineralization is achievable. Some have recognized a tectonic framework and heat-fluid-tectonic relationships, now being given precision by Ivanov (1958), Erickson (1959), et. al. Korzhinskii's (1959) open system thermodynamics approach permits the study of systems which can exchange matter, heat, and also change volume, conditioned by tectonic dynamics. Within the Mendocino-Uinta Geosuture A and B megalineaments and C and D rectilineaments control beryllium emplacement in halo patterns up to 40 miles radius around fluorspar mineralized B megalineaments in a N-S Geosuture. Pneumatolytic, (crystallizing above the critical temperature of water vapor 375.5°C) and hydrothermal (below 375.5°C) deposits occur as replacements in non-pegmatitic rocks, and as high temperature quartz-tungsten-beryllium ores in carbonate regions. Low temperature deposits of beryllium due to chelated complexes which vaporize below 200°C may occur along lineaments parallel to megalineaments. Be-complexes have low instability constants and deposit with the physicochemical lowering of the anionic addenda. Beryllium ores occur in thermodynamic systems unfavorable for polarizable ions, and under high temperature-low pressure conditions.

Distinctions Between Barren and Productive Intrusive Porphyries by *Bronson Stringham*—It has been statistically shown that a great majority of the larger Cretaceous and younger hydrothermal ore deposits of Au, Ag, Cu, Pb, Zn, Mo, Hg, and U in the Basin and Range Province are associated with intermediate to acidic intrusive aphanitic or porphyritic rocks of near similar age. Recent work indicates that, except for the Pacific Coast Ranges and the Mother Lode area, similar ore-porphyry relationships apply to deposits over the entire western U.S. However many intrusive porphyries exist which have little or no associated hydrothermal deposits. Some intrusive porphyries, therefore, seem to be genetically related to ore deposits while others are not. These then may conveniently be classified into 2 categories as barren and productive.

To further aid the ore finder, an attempt is made here to offer criteria which will serve to distinguish barren from productive porphyries.

Among the many suggestive distinctions the following seem to be of most importance. Productive acid porphyry bodies generally are of considerable size and seem to cross cut enclosing rock structures with very little or no disturbance due to intrusive action. On the other hand barren porphyries may be of various sizes but on the whole have a tendency to either be concordant with wall rock structures or, where cross cutting relations exist, show obvious intrusive structural effects such as brecciation, folding, up arching, etc. Feldspar phenocrysts of productive porphyries often show scalloping on a minute scale by ground mass material whereas phenocrysts of barren porphyries show either straight boundaries or conventional resorbtion effects. Other but less diagnostic criteria will be presented.

Structural Control and Localization of Gold-bearing Lodes in Kolar Gold Fields, India by *S. Narayanaswami, Mohamed Ziauddin, and A. V. Ramachandra*—Gold-bearing lodes in Kolar gold field localized in Precambrian Dharwar metavoicanics reveal remarkable structural and stratigraphic controls of high-temperature, hypothermal ore deposits. Fifteen parallel lodes including six gold-quartz lodes and nine gold-quartz-sulphide lodes have been mapped. The Champion quartz lode system has been mined over a strike length of five miles and down to an average vertical depth of 9,000 feet, the maximum depth reached to date being 10,200 feet. The sulphide-bearing Oriental and McTaggart lodes have recently been explored and developed in the northern part of the field.

The lodes are localized along stratigraphic contacts between competent beds of granular, fibrous, or massive amphibolite and schistose amphibolite. They consist of en echelon quartz vein-zones in altered and mineralized wall-rock composed of diopside, hornblende, cummingtonite, epidote and biotite, and flanked by thick micaceous-altered wall-rock. Besides native gold, the ore minerals include chiefly pyrrhotite, arsenopyrite, galena, pyrite, scheelite and magnetite.

Payable ore shoots along the lodes are localized in areas of dilation in the vicinity of en echelon cross-folds and associated en echelon faults. Predominantly dextral en echelon pattern of ore shoots showing north pitch has resulted from dextral cross-folds; these are intervened by sinistral en echelon ore shoots having south pitch in local areas of sinistral folding. The en echelon nature of quartz vein-zones within lodes reflect the above en echelon pattern of ore shoots and cross-folds on which they are localized.

The future exploration for lodes to augment the declining ore reserves will depend on the diligent application of the above structural principles.

Underground Mining

The History and Development of The San Manuel by *F. H. Buchella and J. F. Buchanan*—The San Manuel Copper deposit is located in the Old Nat mining district of Pinal County, Ariz., about 45 miles northeast of Tucson. The orebody is between the towns of Oracle and Mammoth, and the concentrator, smelter, administration building and other plant facilities are located about seven miles southeast of the mine area at the town of San Manuel. Until the advent of the San Manuel mine, the chief producers were the Mammoth and Mohawk mines, located a mile further north, and now owned by San Manuel. Gold, lead, zinc, and some vanadium and molybdenum were the main recoverable metals at these properties when operating. Exploration by churn drilling was started on the San Manuel orebody in December 1944, and completed early 1948. Actual shaft sinking for underground exploration and development started in March 1948 and progressed continually until five shafts had been sunk, and over 20 miles of drifting completed to prepare the first lift for production. The first stope undercut was completed for mine production on January 23, 1956, and a production of better than 30,000 tons of ore per day was reached in early 1958. The concentrator started trial runs on stockpile ore and mine development ore on Oct. 4, 1955, and the smelter produced the first anode copper in January 1956.

Geophysical

Model Studies of an Apparatus for Electromagnetic Prospecting by *H. E. Swanson*—A description of the field apparatus has been published by Brubaker*. Data from laboratory model studies of the in-line and broadside methods of operation are to be presented. The conductor models include a single sheet conductor at several strike and dip angles, and a schistose-type conductor. In addition, data on the effects of the strike length and of the depth of the conductor are to be presented for the broadside method of operation.

* Brubaker, D. G., "Apparatus and Procedure for Electromagnetic Prospecting", Trans. A.I.M.E., Vol. 208, pp. 777-780, July 1957.

Rock Mechanics—Open Pit

Underground Stress Instrumentation by *Robert Stefanko*—Underground stress instrumentation is gaining impetus in the United States due to the availability of improved instruments and the need for more effective strata control to increase productivity while decreasing costs. Instrumentation is classified in this paper as:

1) mechanical types: gages affixed to props, cribs and roof bolts and use of stress-meters in pillars.
2) non-mechanical types: sonic and resistivity measurements as a function of stress.

For the mechanical types bonded electrical wire strain gages are commonly employed. The employment of photoelastic strain gages is suggested as an alternate method to avoid long-term instability due to moisture effects and also to eliminate high-voltage indicators which lack permissibility.

The non-mechanical types offer a greater potential but also are more complex. Because they are non-destructive, i.e., they do not require modification of the mine structure, equilibrium is not changed. The sonic group is further declassified into microseismic or self-induced and pulse-generated types.

Results of research at Penn State by the above instrumentation techniques are discussed in detail and comparisons are made. The lack of knowledge concerning original stress distribution and behavior of the material in situ, complicates reliable calibration for stress instrumentation. To avoid many of these problems, calibration in situ is proposed for increased reliability over laboratory methods.

The Mechanics of Rock Slopes by *D. Hugh Trollope*—The paper attempts a broad classification of rock slopes from the point of view of internal stress distributions. For homogeneous, uniform rock, analytical solutions entailing the classical assumption of rigid-plastic c/ϕ material behaviour is considered in the light of recent developments in soil mechanics theory. The case of jointed fissured rock is analyzed on the basis of the behaviour of discrete granular materials according to a method developed by the author. The theory indicates that floor heave in an open pit mine can be responsible for significant changes in the stress distribution within a rock slope and it points to the critical nature of the part played in the stability problem by ground water seeping towards the cut.

A possible explanation of the origin and magnitude of horizontal pressures in rock masses is developed from the theoretical argument.

Finally suggestions are made concerning appropriate field measurements which should aid in assessing the stability or rock slopes and desirable research developments in both *field and laboratory* testing are noted.

A Method For Determining the True Tensile Strength of Rock by *Niles E. Grosvenor*—The importance of knowing the true tensile strength of rock will be discussed. The standard methods of determining the tensile strength of rock and a new method of determining the tensile strength of rock that has been developed at the Colorado School of Mines will be presented.

Geochemical

Status of Geochemical Prospecting in the U.S.S.R. by *H. E. Hawkes*—Geochemical soil surveys, known in the Soviet Union as "metallometric surveys," are now conducted in conjunction with all general exploration surveys. In 1957, a total of 6,700,000 samples were analyzed, mostly in mobile spectrographic laboratories, for a check list of 10 to 20 elements. The rapidly increasing application of these methods indicate that they are probably successful, although specific case histories of discoveries are not easy to find in the literature. Research on other geochemical methods of mineral exploration is being pushed on a large scale. Particularly significant results are reported on gaseous halos of mercury in soils as a guide to buried mercury-bearing base-and precious-metal deposits, and molybdenum and sulfate in water as a guide to molybdenum-bearing sulfides. Petroleum exploration based on patterns of hydrocarbons migrating upward from deep-lying oil pools has reached a high state of development, and many specific discoveries have been credited to these methods.

Relationship of Carbon in Soils to Graphitic Zones by *William H. Dennen and Harold Linder*—Spectrochemical study reveals that readily measurable quantities of graphitic carbon will weather into the soil over graphitic rocks and that determinations of the carbon content of the "C" soil horizon can be used to detect and delimit graphitic zones.

Geological and Geochemical Factors in the Discovery of Blind Ore in the East Tintic District, Utah by *T. S. Lovering and H. T. Morris*—The Burgin Shaft in the Chief Oxide area of the East Tintic district, Utah, has added another important area of blind ore bodies to the few that occur a mile to the west, from which the district's 75,000,000-dollar production has come. Detailed geologic mapping, laboratory and field studies of rock alteration, and geochemical exploration by the U. S. Geological Survey led to testing the Chief Oxide area with a deep drill hole in 1952. Study of the fossils, lithology, and alteration shown in the drill core below the Chief Oxide alteration patch in the blanket of quartz latite lava resulted in an essentially correct interpretation of pre-lava structure in the strongly discordant underlying Paleozoic rocks in which a mineralized tear fault cuts a strong thrust fault. Mineralogic and geochemical studies of the core showed that ore stage mineralization had occurred; the chance of finding blind lead-zinc ore bodies in the host rocks and structural setting deduced seemed excellent. Subsequent work by Bear Creek Mining Company, which sank the Burgin Shaft, has shown the presence of lead-zinc ore of commercial grade in several separate ore bodies. Exploration is still in progress, and much ground is yet to be tested.

A geochemical anomaly was found at the surface, and though it was not strong it was similar to one found uprake from the great ore bodies of the Tintic Standard mine a mile to the northwest. A second geochemical anomaly was found about two miles southwest of the Burgin shaft, and drilling showed that the anomaly is related to ore in faulted sedimentary rocks below a cover of altered lava.

Solubility of Copper in Natural Waters and its Application to Geochemical Prospecting by *J. A. Sliman and R. M. Garrels*—The stability of azurite, malachite, brochantite, and langite ($Cu_4(OH)_6SO_4.1.3\ H_2O$) in water at 25°C. and 1 atmosphere total pressure were determined by solution and precipitation techniques. Their standard free energies of formation from the elements at 298°K and 1 atmosphere total pressure are: azurite -343.73 ± 0.08 kcal, malachite -216.44 ± 0.05 kcal, brochantite -434.62 ± 0.02 kcal, langite -505.1 ± 0.1 kcal.

Analysis of the solubility data permit calculation of the following dissociation constants:

$$\frac{[Cu^{++}][CO_3^{--}]}{[CuCO_3^{\circ}]} = 10^{-6.9}$$

$$\frac{[Cu^{++}][CO_3^{--}]^2}{[Cu(CO_3)_2^{--}]} = 10^{-10}$$

$$\frac{[Cu^{++}][CO_3^{--}][OH^-]^2}{[CuCO_3(OH)_2^{--}]} = 10^{-15}$$

The preceding data permit calculation of approximate maximum solubilities of copper in natural surface waters containing chiefly sulfate and bicarbonate as anions. Diagrams showing solubility as a function of pH, sulfate, and CO_2 species demonstrate that in many natural waters the chief soluble species below pH 7-- is Cu^{++}, between pH 7 and 10 is $CuCO_3^{\circ}$, and above pH 10 is $Cu(CO_3)_2$. The absolute solubilities appear to be so low that detection of copper by current geochemical prospecting techniques in waters with pH values higher than 7 is unlikely. Exceptions may occur in highly saline waters.

Geochemical Patterns in Certain Ore Deposits by *A. W. Jolliffe*—Geochemistry is concerned with the natural distribution, abundance, and association of all the chemical elements. Its basic data are supplied by chemical analyses of rocks and minerals. Ore bodies, although geological "freaks", represent much the most thoroughly analyzed parts of the earth's crust and are accordingly particularly appropriate subjects for geochemical study.

The essential feature of any ore deposit is that certain metals are 1 concentrated therein far beyond their average amounts in the earth's crust. If attention be focussed on these and the other chemical elements in an ore body, rather than on the minerals into which they may be combined, mineralogically complex ores become much simplified for study and comparison, and marked affinities are disclosed between deposits that may have quite dissimilar mineral assemblages.

Qualitative and quantitative methods of depicting element associations in ore deposits are described. These reveal some rather distinctive patterns which may aid in: 1) elucidating the origin of certain controversial types; 2) outlining geochemical (metallogenetic) provinces for prospecting; and 3) indicating what additional elements should be sought for in various deposits.

Applied Geochemistry in the Canadian Precambrian Shield by *John E. Riddell*—The paper summarizes the opinions of several large exploration groups concerning the usefulness of applied geochemistry as an aid to prospecting glaciated areas of the Canadian Precambrian Shield. The various factors to be used when selecting and applying geochemical techniques in these areas will be discussed.

Geological

Geological Procedure and Control at Steep Rock Iron Mines Ltd. by *C. J. Gauvin*—The geological department is responsible for the technical direction of all work concerned with the finding and outlining of ore and provides the mine operating staffs with the necessary plans and sections to enable them to design pits and underground layouts and to extract ores as required by incoming cargoes. The department prepares grade and ore reserve statistics with a year-end mining recovery factor.

Geological Procedure:	Diamond Drilling Sampling Mapping Plans and Sections
Mining Control:	Daily Surveys and Communications Weekly Production Plans—Tonnages—Grades Monthly Excavation Calculations and Geological Breakdown Year-end Plans and Sections—Production Schedule

The Application of Geology to Exploration and Mining by *Harrison A. Schmitt*—A plea for more emphasis on hard-rock mining geology. An outline of the chief types of ore deposits in Mexico and the Southwest, and the geologic methods thought to be the most useful in their discovery and exploitation.

Geology of the Nakina Iron Property, Ontario by *W. T. Swensen*—The Anaconda Company, through its wholly owned subsidiary The Anaconda Company (Canada) Ltd., has investigated, optioned and partially developed a large tonnage of iron ore amenable to magnetic concentration. The reserves are located in north central Ontario and occur within a twenty-two mile belt of layered and intricately folded metamorphic rocks, close to the north contact of an igneous complex of granite and pegmatite. There are two main ore deposits. Briarcliffe is a steep to vertically dipping body 100 to 500 feet wide and over a mile long. The Two Mile Lake deposit is flat dipping and confined to an open, asymmetrical syncline; it is approximately a mile wide and 250 to 400 feet thick. On its flat easterly plunge, it is saucer-like in shape and is amenable to open-pitting for an east-west distance of several thousand feet. Its further extension has been indicated for at least three miles by magnetometer work in conjunction with diamond drill tests.

Iron Deposits of the Wabush Lake Area, Newfoundland, Labrador by *R. D. MacDonald*—The ore body described is one of a group of iron ore bodies situated in the Wabush Lake area of south-western Labrador. The ore consists of a granular aggregate of specularite, magnetite, quartz and silicate accessories. It grades 41 pct in iron and therefore falls in the group of "beneficiating" iron ores.

The ore occurs in a metamorphosed iron formation that lies within a stratigraphic sequence of quartzite, micaceous to garnetiferous quartzosegneisses, hornblende and grunerite gneisses and micaceous schists. The formations have been folded, drag-folded, sheared and faulted during the period of metamorphic activity.

The ore body shows considerable outcrop and was located by standard prospecting and geological field methods. Magnetic and gravimetric methods were used to outline the limits of the body. Preliminary diamond drilling and bulk sampling has been done to establish grade and metallurgical characteristics of the ore.

Petrology of the Magnetic Taconites of the Eastern Mesabi District, Minnesota by *James N. Gundersen*—The Biwabik iron-formation of the Eastern Mesabi district has been substantially metamorphosed and in addition to mainly quartz and magnetite contains a variety of minerals, especially silicates. Current large scale mining and beneficiation have warranted a detailed study of the mineralogical variations of the magnetite-bearing taconites in this district.

Lateral variations in ease of blasting and beneficiation are found to be closely related to the silicate mineralogy and grain fabrics shown by the rocks. In general, taconites containing locally abundant amounts of metamorphic silicates, particularly fibrous amphiboles, are usually difficult to break whereas the more quartzose varieties are more easily mined. The gross mineralogy of the iron formation members is somewhat similar, but the 'concentratibility' of a given taconite type is dependent primarily upon the size and degree of dissemination of the magnetite grains and only secondarily upon the association of magnetite with other minerals of the formation.

Additional abstracts received before the deadline will be published in the January issue.

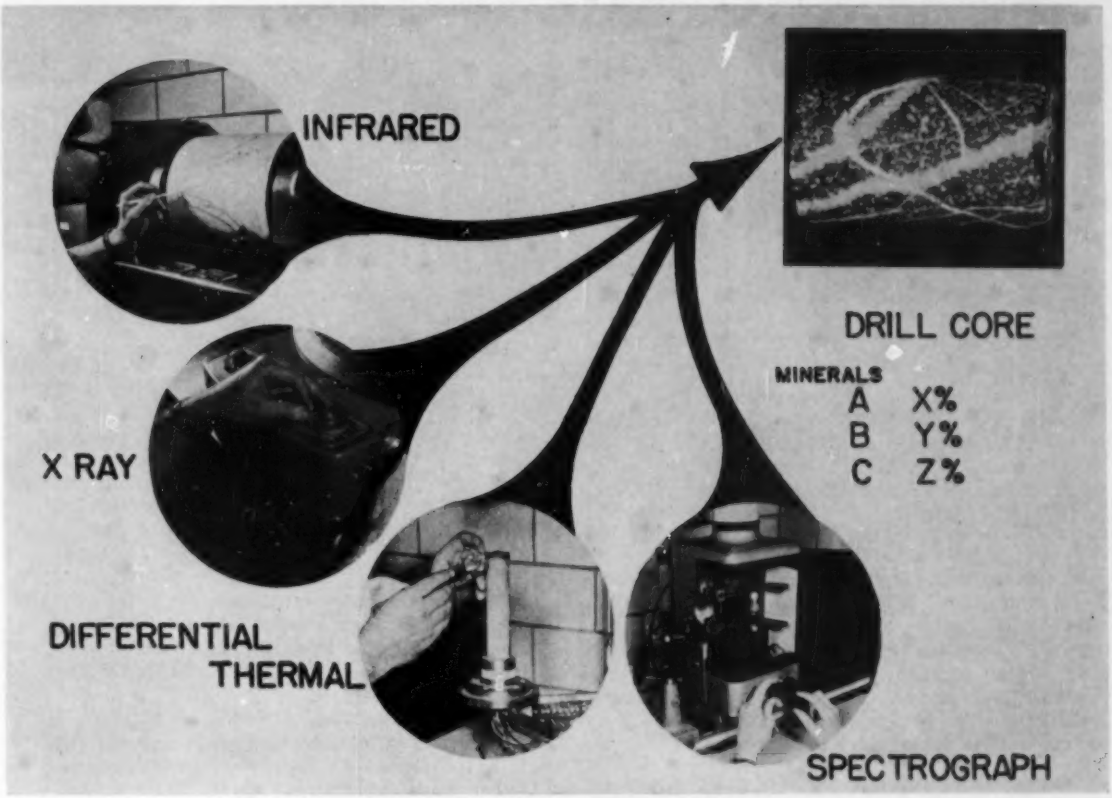

Fig. 1—Diagram of integrated instrumentation.

QUANTITATIVE MINERALOGY AS A GUIDE IN EXPLORATION

by R. J. P. LYON and W. M. TUDDENHAM

In many areas surrounding the orebodies in mining districts rocks have been bleached and altered by the ore-forming solutions and have been oxidized during later weathering processes. A number of the rock-forming silicates have been broken down to clay, sericitic micas and chlorites have been developed, and pyrite may be found hundreds of feet outside the economic limits of the orebody. These halos of altered ground are prime targets used by geologists in many districts to delineate promising sites for drilling.

Both in the field and in the laboratory it is often difficult to map these mineralogical changes in the halos in detail without numerous petrologic examinations. The secondary minerals are generally fine-grained, and since conversion of one mineral to another is often progressive, many alteration processes have not proceeded to completion (feldspars to clay to sericite mica). Qualitative detection of these minerals is difficult; quantitative determination is frequently impossible.

R. J. P. LYON, and W. M. TUDDENHAUM, Members AIME, are Senior Scientists, Kennecott Copper Research Center, Salt Lake City. TP 59177. Manuscript, April 17, 1959. San Francisco Meeting, February 1959. AIME Trans., Vol. 214, 1959.

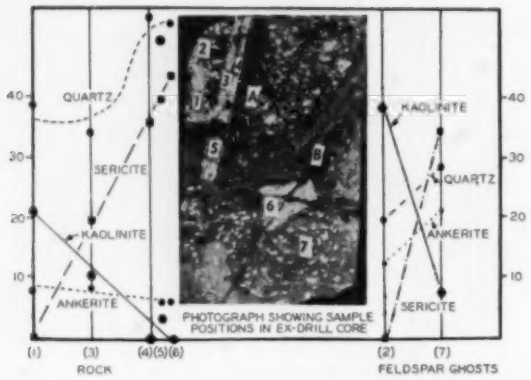

Fig. 2—The quantitative mineralogy of several alteration envelopes in drill core section (3, reduced approximately 12 pct.) The freshest rock (1) contains kaolinized feldspar phenocrysts (2). Alteration envelopes are chloritic fringe (3) and quartz-sericite zones (4, 5, 6), which contain feldspar ghosts (7).

Many studies made in the past have suffered from basic inadequacy in determining the fine-grained minerals. In consequence, the field mapping and ultimately the usefulness of the alteration study have been seriously handicapped. Quantitative mineralogy of samples collected on a grid basis in areas of pervasive alteration offers a guide little used to date in exploratory drilling.

INTEGRATED METHOD VS MICROSCOPE APPROACH

At Kennecott's Research Center techniques of mineral identification and quantification have been developed to aid the company's exploration department. Almost all samples received are now processed with the infrared spectrophotometer, X-ray diffraction, and differential thermal analysis units on a routine basis. These semi-automatic instruments are unaffected by the original grain size of the minerals and greatly assist rapid quantitative determinations. When coupled with thin-section and polished-section study of the rocks, this integrated approach gives better overall coverage, combining the area of mineralogy in which each particular instrument is most sensitive (Fig. 1).

Clays and hydrated minerals are thus best detected in thermal and infrared analysis, silicates by infrared analysis, micas and montmorillonite clays by X-ray diffraction, and sulfides and oxide minerals by examination of polished section. The textural relationship of adjacent minerals is seen most clearly in polished and in thin sections. Each instrument has a field of maximum sensitivity, and no one unit can possibly cover the range of minerals involved in mining and metallurgical research.

An excellent treatment of the problems encountered with optical determination of quartz in the presence of the talc and clays of fine-grained rocks was given 1949 by Foster,[1] who clearly showed that instrumental analysis is superior for the finer-grained materials. On the average, 30 pct of quartz was found by X-ray analysis, whereas only 5 pct was visible optically in the same samples. During the past three years the writers have found that infrared absorption analysis gives the most reliable single approach in quantitative mineralogy, being much less sensitive to the preferred orientation that makes X-ray diffraction analysis so hard to quantify.

To form the sample material for work with these instrumental methods, the Research Center now uses pulps exactly as prepared for chemical assays. Qualitative and quantitative mineralogy can be obtained ranging from samples of 1 mg, carefully drilled from a single phenocryst or groundmass area, to pulps prepared from lengths of drill core or from yearly mill head composites. This offers a great advantage over the usual thin-section mineralogical analysis.

The volume of rock contained in a thin section is only about 0.025 cc. To measure the average mineralogical composition of 100 ft of drill core it is necessary to assume that one thin section is a representative sample of that 100-ft section of core and then statistically examine the data to find out if the sampling has been adequate. It would be hard to determine the bulk mineralogy of mill feed by point-counting thin sections, but a method utilizing a powdered sample readily determines the mineralogy of this type of material. In routine mineralogical analysis of drill cores up to seven minerals have been quantitatively determined in a single analysis.

Table I lists the concentration limits for detection in routine infrared absorption analysis for typical minerals occurring in drill cores. Similar data are available for the X-ray[2] and differential thermal analysis[3] methods.

With the integrated approach, over 75 pct of the mineral content of the sample can be accounted for in a permanently recorded form. The personal factor of the operator is reduced to a minimum. A full petrographic study of an altered rock, including point-counting analysis to determine the modal composition, can take up to 8 hr; quantitative infrared, thermal, and X-ray analysis can each be completed in 1 hr.

DETAILED STUDY OF SMALL SAMPLES

Single Orthoclase Phenocryst

A single orthoclase phenocryst 3 mm square occurred in a quartz-sericite alteration zone around a sulfide veinlet. This was selected to determine the quantity of sericite formed in this phenocryst during the alteration. Infrared analysis of a 2.5-mg sample carefully drilled from the phenocryst showed 25 pct sericite, 4 pct kaolinite, 55 pct orthoclase, 10 pct albite, and 3 pct carbonate. The changing alteration of the small orthoclase phenocrysts that takes place within each of the adjacent alteration envelopes can

Table I. Estimated Infrared Limits of Detection and Sensitivity for Quantitative Analysis in Typical Rock Environments

Mineral	Rock Type	Lower Limit of Concentration for Detection, Pct	Percent of Sensitivity at 50 Pct Concentration
Carbonates	Any rock	0.5	±3
Quartz	Any rock	1	±3
Plagioclase (An_5 to An_{30})	Any rock	3	±8
Orthoclase	Granite	3	±8
Sericite	Alteration	15	±5
Biotite	Schist	50	±10
Augite	Diorite	10	±8
Kaolinite	Alteration	3	±3
Montmorillonite	Alteration	25	±10
Alunite	Alteration	3	±8
Jarosite	Alteration	3	±5
Chlorite	Alteration	15	±10

Fig. 3—A close-up of area B in Fig. 2 showing one side of a quartz-sericite envelope adjacent to a vein (vertical on right). Kaolinite zone (sample type 1) at left shows how quartz-sericite zone (samples 4-6) encroaches on the phenocrysts. Network of fine quartz ribbing is noticeable only in the quartz-sericite band. X12, reduced approximately one fourth.

be studied easily by this method. This type of work on single crystals is perhaps the field most suited for infrared analysis.[4]

Alteration Envelopes Adjacent to Veinlets

Altered wall rock adjacent to two veins in an andesitic tuff was selected for quantitative study of sericite and quartz alteration of the feldspar. Fig. 2 shows the sampling pits from which the powders were drilled and the location (B) of the close-up detailed photograph (Fig. 3). The data obtained from infrared analysis are expressed graphically in Fig. 2. The veins, which contain quartz, pyrite, and chalcopyrite, were deliberately excluded in the samples so that vein material would not mask the quartz in the adjacent wall rocks.

In the Fig. 3 micrograph the slight vertical illumination used in addition to oblique lighting shows up a ridge of harder material surrounding each feldspar ghost. This ridge appears in the quartz-sericite envelope but not in the chloritic fringe or clay zones; it does not seem to increase proportionately as the veins are approached. The ridge can be correlated with the increase of quartz content between samples 1 and 4, 5, and 6. This shows that the silica released when kaolinized feldspar is converted to sericite is reprecipitated outside each *feldspar* crystal as a hard wall. By defining accurately the content of free quartz and other silicates in the sample, infrared analysis gives valuable information on the movement of SiO_2 during the chemical reactions of alteration.

Petrography by Instruments—Rock Type Determination

Another quantitative application of this method has been the independent estimation of essential mineral content in a granite (G-1) whose mineralogical mode is known. The quartz content, microcline content, and plagioclase type and content of the powdered sample have been determined by instrumental analysis, details of which have been reported elsewhere.[6]

By rapidly determining the quartz: plagioclase: orthoclase ratios of rocks, it is possible to plot the data on composition diagrams and quickly deduce their petrologic types. This method has been applied on a routine basis to about 400 rocks in the general acid composition range.

APPLICATION TO EXPLORATION PROBLEMS

Areal Sampling of a Serpentine Belt

In prospecting an area of altered ultrabasic rocks, it was advantageous to know the ratio of chrysotile to antigorite in the natural mixtures of these minerals (usually called serpentine). It is difficult to distinguish them optically and hard to determine their relative abundance. To guide exploration a quick, accurate, and reproducible means of estimating the mineral content of the samples was desired.

As serpentine samples responded very well to both infrared and differential thermal analysis, it was possible to make quantitative determinations of the end members, chrysotile and antigorite. Instrumental data for the end members and a natural mixture of the two are shown in Fig. 4. Both instruments could be operated in a simple base camp laboratory, providing readily available information at nominal cost.[6]

Copper Prospect in Volcanic Rocks—Sampling and Analysis

The area of isolated outcrops of pervasively altered andesite lavas, tuffs, and agglomerates was 80 pct obscured by ice and glacial moraine. The study was to correlate the outcrops and drill cores and to give an idea of the size and type of zonal pattern of the alteration and its relationship to the metallized ground.

A suite of 28 samples collected over an area of 2 sq miles during field mapping and diamond drilling was examined in the laboratory. Sample locations were spotted on outcrop maps of the area, where the field parties had logged alteration types, but the quantitative data were obtained independently of these descriptions.

The samples were quartered, crushed as for assay pulps, and processed by differential thermal, infrared, and X-ray diffraction analysis. Specimens were mounted for polished-section study of the sulfide type and distribution, and thin sections were made for microscope study. The petrographic study was

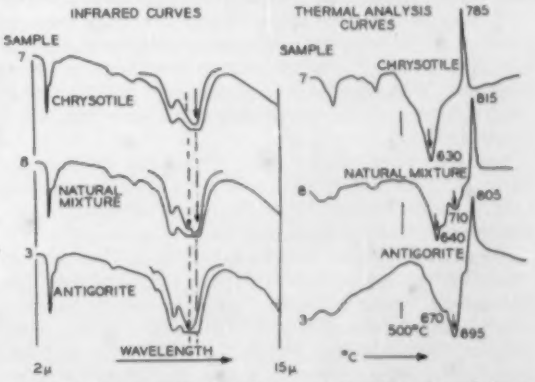

Fig. 4—The quantitative data may be determined from both the infrared curves and the thermal analysis curves for chrysotile-antigorite natural mixtures. Arrows indicate the criteria that are important for quantitative data.

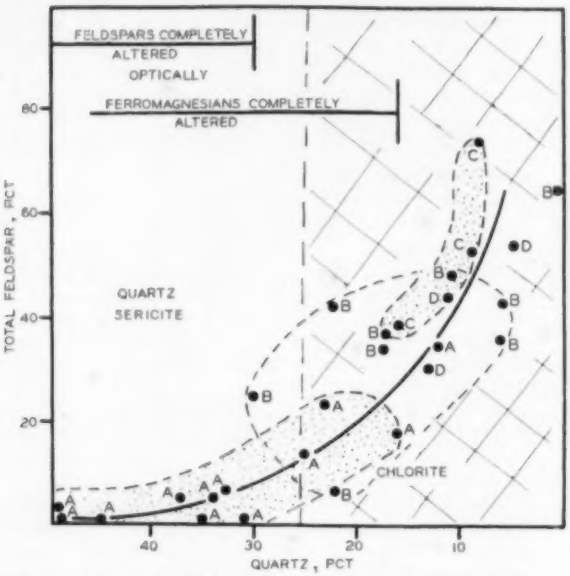

Fig. 5—The relationship between plot of quartz-total feldspar and degree (A and C, stippled) of alteration. Note broad division on the mica type (cross-hatched).

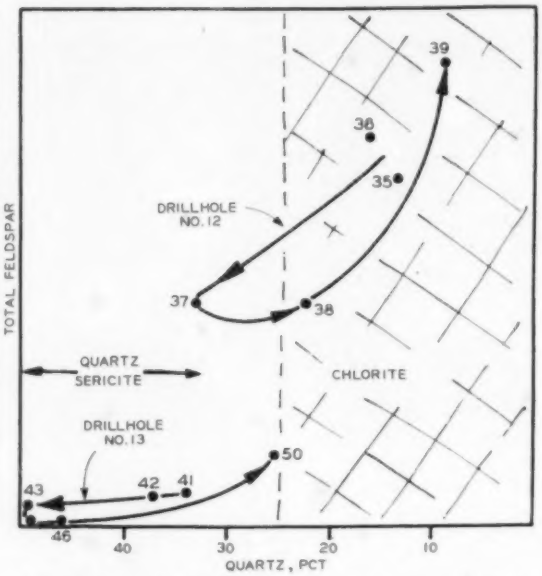

Fig. 6—The relationship between the same drillhole samples (12 and 13) shows the progressive changes in mineralogy and in the degree of alteration. (Curves are displaced vertically from Fig. 5).

performed by a different operator so optical and instrumental data could be obtained independently.

Data obtained from the various methods were as follows:

Microscope Analysis: Rock texture, chlorite content, and the minerals present in small amounts were determined. The degree of alteration of feldspars and ferromagnesians was assessed and classified as follows: *A*, both 100 pct altered; *B*, ferromagnesians 100 pct altered and feldspars 90 to 100 pct altered; *C*, ferromagnesians 100 pct altered and feldspars 80 to 90 pct altered; *D*, ferromagnesians 80 to 100 pct altered and feldspars less than 80 pct altered.

The type and ratio between opaque minerals and sulfides were obtained by study of polished sections.

Differential Thermal Analysis: This indicated the type of clay mineral and mica present. Quantitative data were difficult to obtain, as oxidation of sulfides invariably masked the thermal effects.

X-Ray Diffraction: X-ray diffraction indicated the type of mica mineral and gave a semi-quantitative determination of quartz content. Preferred orientation was found to be a very complex problem even when internal standards (brucite, fluorite, etc.) were used.

Infrared Absorption: This yielded the main qualitative and quantitative data on the quartz, feldspar, and sericite content. The type and content of the carbonates were determined by this instrument.

Discussion: Figs. 5 through 8 graph the serial variation of one or two minerals with another. Instrumental determinations of the quartz content are plotted as the abscissa with total feldspar content as the ordinate, indicating that feldspar content varies inversely with quartz content following a declining curve. At 20 pct quartz there is about 20 pct residual feldspar, whereas at 30 pct quartz only 7 pct feldspar remains. Given a quartz composition of a rock in the area, the content of several other minerals can be predicted. There is a definite relationship among minerals in the alteration halo which can be determined and contoured.

In detail, the figures show several interesting related sets of data. In Fig. 5 the microscopically determined degree of alteration (A-D) has been indicated near each sample point plotted from the quartz-total feldspar ratio. This shows the direct relationship between quartz-feldspar ratios and the visible degree of alteration. The cross-hatched field covers those samples in which chlorite occurs. In samples with lower quartz content chlorite is present, whereas those with higher quartz content have increasing amounts of sericite. A given point on an alteration curve, determined by the content of quartz and total feldspar, also indicates the type of mica present.

In Fig. 6 the sample from drillholes 12 and 13 have been separated and the decline curves displaced vertically. (Feldspar ordinates are on the same scale but displaced.) Drillhole 12, which was collared (samples No. 35, 36) in the chlorite zone, passed into the quartz sericite zone (No. 37) and returned into the chlorite zone in depth (Nos. 38, 39). Drillhole 13, collared in the sericite zone (No. 41), remained in that high alteration zone (Nos. 42 through 46) but bottomed in less altered ground (No. 50). Gypsum veinlets were found only in samples of the strongest altered ground (Nos. 42, 43, 45). Thus progressive degrees of alteration can be assessed within individual drillholes.

Fig. 7 shows the type of residual plagioclase for points plotted from their quartz and total feldspar contents. Results suggest that albitization steps during early and middle stages of alteration are reversed as the grade of alteration increases, and a residual amount of An_{15} remains until a late stage in the process. Much more definitive data are required, but the determination of feldspar type when feldspar is below 10 pct in a highly altered and fine-grained rock unfortunately presents many difficulties.

Fig. 8 shows the carbonate type and content of the same samples plotted on the same quartz-total feldspar basis. Beneath the curves are histograms of the chalcopyrite (black) and pyrite (stippled) contents of the samples, determined by a polished-section study. It is noticeable that dolomite occurs with high quartz, high gypsum, and low feldspar and with sericite and pyrite. Calcite occurs with chalcopyrite in a chlorite-rich, low-quartz (less than 25 pct) high-feldspar sample. Ankerites occupy an intermediate position. Carbonate content increases somewhat as alteration proceeds, but its composition may be directly related to the type of sulfide and degree of alteration.

Correlation of Data: Fig. 5 shows good correlation between microscope data and instrumental data of the rock alteration. The microscope data, obtained independently, are thus compared with the infrared, X-ray, and differential thermal data. The data obtained principally by infrared analysis are obviously more precise and indicate the various alteration stages more accurately than the visual method.

Suggestions for Further Drilling: Drilling for hypogene copper in the rocks of this area should be confined to the chlorite-calcite alteration zones where quartz is low, feldspars are still visible, and original ferromagnesians are not yet converted to sericite.

SUMMARY

Several methods of mineralogical assistance in exploration have been shown. These provide mineral data with which to define or contour the drilling targets more exactly. The following instruments and techniques have been used in an integrated approach:

1) Infrared absorption.
2) X-ray diffraction.
3) Differential thermal analysis.
4) Petrographic, metallographic, and binocular microscopes.

These techniques were applied successively to the following problems:

1) Alteration of single feldspar phenocryst.
2) Alteration of rock in selvages around a sulfide veinlet.

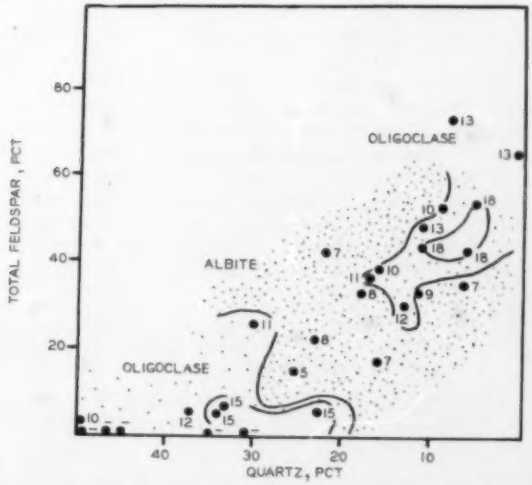

Fig. 7—Relation between Fig. 5 quartz-total feldspar plots and An content of their residual plagioclase.

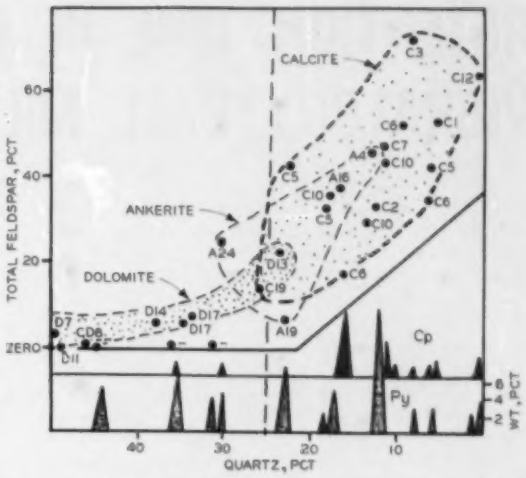

Fig. 8—The relationship between the same quartz-total feldspar plots and carbonate type (C, calcite; A, ankerite; D, dolomite) and content (A15). Histograms show the chalcopyrite content (black) and the pyrite content (stippled) for the same sample plots (see Fig. 5).

3) Quantitative mineralogy of large samples, rock type.

4) Area sampling for specific mineral content in a serpentine belt.

5) An exploration problem where outcrops are very limited and drillholes are few.

A single drillhole intersects only *one part in 700 million* of each square mile area, without consideration of depth as a further variable. Grid drilling is becoming increasingly expensive and the maximum data must be obtained from each hole. How near is the ore at each hole or, given two holes, where should the third be placed to intersect the ore? How close is a *near miss* drillhole? These are questions of great economic importance, particularly in determining the next drilling site, and anything that can be found to aid this decision will take some of the gamble out of the earlier stages in the search for metals.

The authors gratefully acknowledge the assistance of S. R. Zimmerley, Director of Research, Kennecott Copper Corp., who has vigorously supported the application of quantitative data to mineralogy. They also extend thanks to their colleagues, R. E. Wood, C. S. Thompson, G. Burgener, and M. C. Randle, without whose help much of the basic data would not have been determined.

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Discussion of this article sent (2 copies) to AIME before Jan. 31, 1960, will be published in MINING ENGINEERING.

RETENTION TIME IN CONTINUOUS VIBRATORY BALL MILLING

by D. W. FUERSTENAU

Recently R. J. Charles[1] showed that comminution of brittle or semi-brittle materials in batch operations is described more appropriately by a variable energy relationship than by the specific relationships proposed by Rittinger,[2] Kick,[3] and Bond.[4] That is, the value of n in the empirical differential operation which applies to crushing and grinding (Eq. 1) is variable. Independently, Holmes[5] developed an identical generalized equaton for size reduction. The experimental data of Charles and Holmes show that the value of n is determined by the material and the comminuting machine and is constant for a given combination of these two conditions.

The general objective of the present article is to extend the Charles-Holmes concepts to continuous ball milling. The specific objective is to analyze the operation of a vibratory ball mill dry-grinding chromite in a continuous open circuit and to develop an equation for the comminution of chromite in this mill.

Basic Principles: In a batch mill the length of time during which the material is ground is a direct measure of the energy expended on the material, except possibly for exceedingly fine grinding. However, in a continuous operation, the fraction of the total expended energy which is useful for grinding will vary according to feed rate and amount of material in the mill. If the amount of material within a continuously operating vibratory mill is low enough so that only part of the expended energy is used for grinding, the extent of size reduction at constant power input must depend upon the length of time the material is retained within the mill, namely, upon retention time. The following analysis pertains to a continuous mill operating under these conditions.

The empirical differential equation that applies to the comminution of brittle materials is:[6]

$$dE = -C\,dx/x^n \qquad [1]$$

where dE is an infinitesimal energy expenditure, C a constant, dx an infinitesimal size change, x the particle size, and n a constant. For continuous grinding in an open circuit at constant power input, P, Eq. 1 must be written as

$$(dt_r)_P = -C'\,dx/x^n \qquad [1a]$$

where dt_r is an infinitesimal time during which a particle of size x is in the mill, and C' is a constant.

A ground product never consists of particles of single size but always comprises a distribution of sizes. In comminution, the expenditure of energy causes a lateral shift in the size distribution.[1, 7, 8] The general objective of any engineering study of comminution is to correlate the magnitude of this size distribution shift with the energy expended, the ultimate aim being to cause the greatest shift with the least amount of expended energy. Although a number of criteria can be used to measure this shift, Schuhmann's size modulus has been found convenient.[1] Mathematically, the Schuhmann size distribution can be expressed as follows:[9]

$$y = 100\left(\frac{x}{k}\right)^\alpha \qquad [2]$$

or in differential form:

$$dy = \left[\frac{100\alpha}{k^\alpha}\,x^{\alpha-1}\,dx\right] \qquad [1a]$$

where y is percentage of material finer than size x, α is a constant that determines weight distribution among particles of various sizes, and k the size modulus that denotes the theoretically maximum-sized particle in any size distribution.

By considering the energy required to reduce an element of weight of material, dy, from size x_m to size x, the element of time during which the material must remain in the mill at constant power will be

$$\left(dt_r\right)_P = \int_{x_m}^{x} \frac{-C\,dx}{x^n}\,(dy) \qquad [3]$$

Summing up all the elements of weight from zero to 100 for a product that conforms to the Schuhmann size distribution yields

$$(t_r)_P = \int_{x_0 \to 0}^{x} \int_{x_m}^{x} -\left(\frac{C\,dx}{x^n}\right)\left(\frac{100\alpha x^{\alpha-1}\,dx}{k^\alpha}\right) \qquad [4]$$

D. W. FUERSTENAU, Member AIME, is with the Department of Mineral Technology, University of California, Berkeley. TP 6081O. Manuscript, Jan. 5, 1959. New York Meeting, February 1960. AIME Trans., Vol. 214, 1959.

where x_o, the size of material when y is zero, approaches zero. Thus for reducing material of large initial size to a product conforming to the Schuhmann size distribution of size modulus, k, the retention time within a continuously operating mill is given by

$$(t_r)_p \approx \frac{C\alpha}{(n-1)\ (\alpha-n+1)}\ k^{1-n} \approx Ak^{1-n} \qquad [5]$$

Eq. 5 affords a method for obtaining n. If an ore is ground in the vibratory ball mill under conditions where the retention time varies, a log-log plot of the size modulus, k, vs the retention time at constant power, $(t_r)_p$, should yield a straight line of slope 1-n. For this method of determining n to be used, the material should have a reduction ratio great enough for the product to assume its natural value of α for the particular machine, and the approximation concerning the feed term must be valid. If the mill is operated at different power settings, the extent of size reduction must be stated as a function of retention time and power.

Where the feed and product size distributions have identical values of α, and where the feed term is not negligible, the general equation will have the following form:

$$(t_r)_p = A(k_p^{1-n} - k_f^{1-n}) \qquad [6]$$

where k_p and k_f are the size moduli of the product and feed, respectively. Thus a plot of retention time at constant power input vs the quantity, $(k_p^{1-n}-k_f^{1-n})$, should be a straight line of slope A. A plot of this type is used to evaluate A in Eq. 6.

Materials and Method: A 15x15-in. Allis-Chalmers vibratory ball mill was operated in continuous open circuit to dry grind chromite. This mill, which was charged with 332 lb of balls (3 pct 1 in. by ⅞ in., 60 pct ⅞ by ¾ in., 37 pct ¾ by ⅝ in.), required 5.60 ± 0.05 kw for operation at a frequency of 1260 rpm and a vibration radius of 9/32 in. With this ball load the mill was filled to 84 pct capacity. Regardless of feed rate, power to this mill was constant because weight of ore in the mill was negligible compared to the total weight of the mill.

To avoid dust loss the system from the feeder to the product hopper was sealed. The mill was fed dry from an Omega Gravimetric Model 50-8 feeder. Before each pass through the mill, the feeder was calibrated with the material to be fed to the ball mill. Accuracy of the feed rate during the runs was well within 1 pct. A flexible rubber chute connected the feeder with the ball mill. Since the mill was not air-swept, material passed through it by free flow and was discharged through a rubber hose into a covered hopper.

The ore being ground in the vibratory ball mill was Transvaal chromite ground previously in an Aerofall mill, nominally through 28 mesh. Since the product was the horizontal classifier discharge from the Aerofall mill, many of the fines had been removed and consequently the slope of the Schuhmann curve, α, for this material was high, i.e., 1.83 (see Fig. 1).

The procedure used in the experimentation was to pass about 1000 lb of ore through the mill at 1200 lb per hr. The product from the mill was passed through the mill again at 1200 lb per hr until five passes had been made. In each case, samples of the product were taken after 5, 10, 20, 30, and 40 min of operation. Size distributions of these samples were identical, which shows that steady state had been reached before 5 min had elapsed. While the mill was operating at steady state, the feed was shut off and the mill was stopped almost instantly with a wedge. The contents of the mill (balls plus ore) were carefully removed and separated, and the amount of ore retained in the mill was weighed so that average retention time could be determined. Repeat runs at a feed rate of 1200 lb per hr showed that the amount of ore retained in duplicate runs varied by no more than 4 pct. Four duplicate runs on ore that was 95 pct −325 mesh gave retention times agreeing within 1 pct. Before each subsequent run the mill was recharged with its contents. This procedure was repeated at a feed rate of 600 lb per hr, but at this lower feed rate only three consecutive passes were made.

Sizing was carried out by wet and dry-sieving and the −400 mesh material was sized with an Andreason pipette.

Experimental Results: Fig. 1 presents size distributions of the original feed and the products from each of the five consecutive passes through the mill at 1200 lb per hr. These data show that the product from the first pass through the mill has attained the equilibrium value of α, namely, 0.80, and that the size distributions are shifted laterally with each subsequent pass through the mill. In each case the size distributions are parallel straight lines over an important part, and the size modulus is the extrapolated straight-line portion to $y = 100$. Fig. 2 presents the size distributions for chromite ground in three consecutive passes through the mill at 600 lb per hr. In this case the curves again are parallel and α is again 0.80 in each case. Comparison of Figs. 1 and 2 shows that the product obtained by three passes through the mill at 1200 lb per hr is essentially identical to that obtained by two passes at 600 lb per hr.

Table I presents both the weight of material retained in the mill after each pass and the average retention time, t_r, for each pass. Study of Table I shows that the amount of ore in the mill decreases in general as the ore becomes finer. Only 12.5 lb of ore were in the mill at the highest feed rate, which means that retention time in the mill was only 0.63

Table I. Weight of Ore in Mill and Retention Time for Each Pass

	1200 Lb Per Hr Feed Rate				600 Lb Per Hr Feed Rate			
No. of Pass	k_p, Microns	Ore in Mill, Lb	Ret. Time, Min	Cumulative Ret. Time, Min	k_p, Microns	Ore in Mill, Lb	Ret. Time, Min	Cumulative Ret. Time, Min
1	200	12.6	0.63	0.63	120	10.1	1.01	1.01
2	100	10.3	0.51	1.14	67	5.1	0.51	1.52
3	67	6.7	0.34	1.48	44	5.1	0.51	2.03
4	46	8.9	0.44	1.92				
5	37	7.8	0.39	2.31				

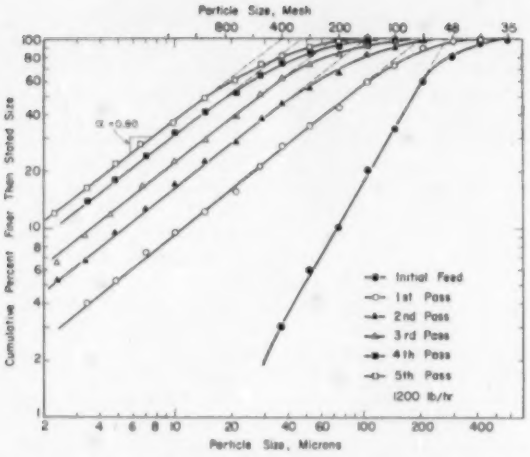

Fig. 1—The above graph shows the size distributions of chromite as a function of the number of passes through the vibratory ball mill at a feed rate of 1200 lb per hr.

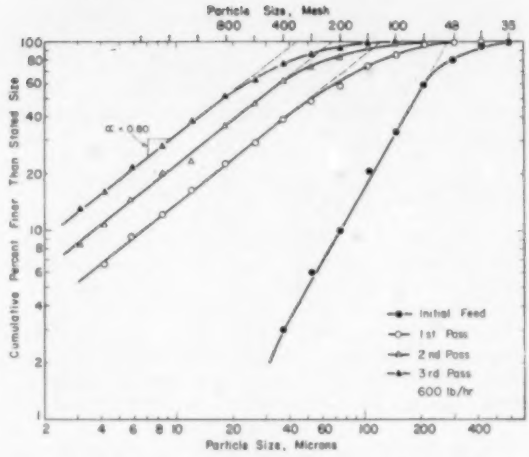

Fig. 2—The above graph shows the size distributions of chromite as a function of the number of passes through the vibratory ball mill at a feed rate of 600 lb per hr.

min during the first pass at 1200 lb per hr. The slightly larger amount of ore in the mill during the fourth pass is real because the same phenomenon was observed when the runs were repeated. Apparently ore of this size flows through the mill slightly slower than that of the third pass and fifth pass. At a feed rate of 600 lb per hr, there is somewhat less material within the mill than at the feed rate of 1200 lb per hr but the retention is somewhat greater. In Table I the cumulative retention time, $(T_r)_p$, is also presented, that is, after two passes the total retention time is the retention time for the first pass plus that for the second. As mentioned earlier, the product obtained by three passes at a feed rate of 1200 lb per hr is identical to that obtained by two passes at 600 lb per hr. As anticipated, the cumulative retention time required for production of this product was essentially the same for the two feed rates, namely, 1.48 min vs 1.52 min, which lies well within the experimental limit of error.

Since relatively coarse chromite was ground at constant power in the vibratory ball mill, n can be evaluated according to Eq. 5 by plotting on log-log paper the size modulus, k, vs the cumulative retention time, $(T_r)_p$. The data obtained at a feed rate of 1200 lb per hr and 600 lb per hr, which are plotted in Fig. 3, fall on a single straight line. The slope of this is −0.78. Since the slope of the curve is equal to the quantity, 1-n, the value of n for the comminution of chromite in the vibratory ball mill is 1.78.

An equation analogous to Eq. 6 can be written for the comminution of chromite in the vibratory ball mill for conditions where the feed term in Eq. 4 is not negligible and where size distribution of feed parallels that of the product. This can be done by considering the product from the first phase through the vibratory ball mill to be the feed for succeeding passes. For evaluation of Eq. 6, k_f will then be the material from the first pass and k_p the product from each of the succeeding four passes at 1200 lb per hr. The data for material ground at 600 lb per hr will be treated similarly. In Fig. 4 the cumulative retention time, $(T_r)_p$, is plotted vs $(k_p^{-0.78} - k_f^{-0.78})$ for the two different feed rates. This figure shows that the quantity, $(k_p^{1-a} - k_f^{1-a})$, depends on retention time and is independent of feed rate. The slope of the line drawn from the data obtained on grinding chromite (Fig. 4) is 38. Thus the continuous vibratory ball milling of chromite is described by the following equation if the feed and product have identical values of α:

$$(T_r)_p = 38(k_p^{-0.78} - k_f^{-0.78}) \text{ minutes} \qquad [7]$$

Discussion of Results: The experimental data reported in this paper show that for a vibratory ball mill operating continuously in open circuit, at constant power input, size moduli of the products are determined by total retention time within the mill, regardless of feed rate. Thus, for a continuously operating low-level discharge mill retention time determines how long any given particle is subjected to the mill action. In batch grinding the total grinding time is the retention time, and doubling the grinding time doubles the retention time. However, in continuous grinding the factors which determine retention time are complex in that retention time depends on flow characteristics of the material passing through the mill. For dry grinding in a vibratory mill, the scale-up of batch laboratory tests to continuous operation will be difficult without a knowledge of retention time, and this may entail experimental determination of retention time.

The data presented in Table I indicate that retention time must be included in a statement of grindability for this system. For example, consider the comminution of the −28 mesh chromite feed to a product with a size modulus of 67 μ in a 15-in. vibratory ball mill drawing 5.60 kw of power. To do this in open circuit at a feed rate of 1200 lb per hr three passes through the mill are necessary, whereas at 600 lb per hr only two passes are required. Thus, at a feed rate of 1200 lb per hr, the total energy requirements are 28 kw-hr per ton, whereas 37 kw-hr per ton are required to grind it at the rate of 600 lb per hr. If the total energy only were considered, it would be concluded that grindability depends upon feed rate. However, grindability of the ore does not vary with feed rate; only the retention time varies, and this in turn determines the fraction of the total energy which is useful for grinding. Therefore, for continuous grinding a statement of grindability must include an energy utilization fac-

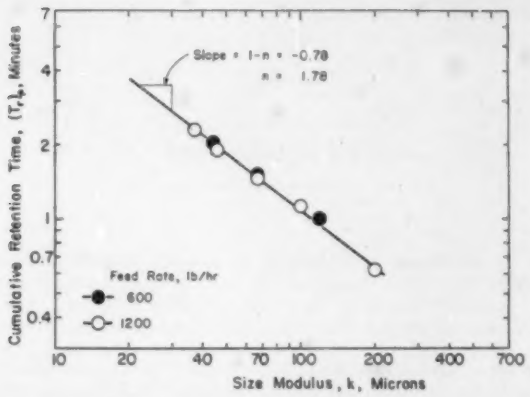

Fig. 3—Retention time–size modulus graph for chromite ground in continuous, open-circuit vibratory ball mill.

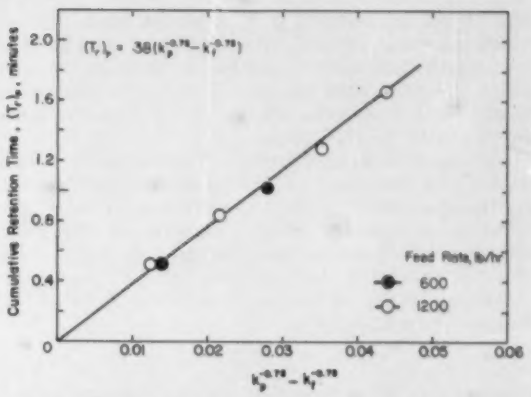

Fig. 4—Cumulative retention time as a function of $(k_p^{-0.78} - k_f^{-0.78})$, when product from first pass through the vibratory ball mill is considered to be the feed.

tor, f, which determines the fraction of the total energy that is being utilized for grinding. For continuous grinding the grindability, G, which is the energy expended per unit weight to reduce a material from size modulus k_f to k_p, is stated mathematically in terms of the power to the mill, P, the feed rate, F, and the energy utilization factor, f, as follows:

$$G = \frac{P}{F} \cdot f \qquad [8]$$

The factor f must depend on retention time. It will be the ratio of the retention time t_r to the hypothetically optimum retention time t_{rm} or it will be the ratio of the weight of ore W_r in the mill under steady state conditions to the optimum weight W_{rm}, which is the amount of material necessary to utilize the energy put into the mill.

$$f = \frac{t_r}{t_{rm}} = \frac{W_r}{W_{rm}} \qquad [9]$$

Thus the grindability of an ore in a continuously operating mill will be

$$G = \frac{P}{F}\left(\frac{W_r}{W_{rm}}\right) \qquad [8a]$$

The grindability of −28 mesh chromite to a size modulus of 67 μ can now be considered using Eq. 8a. At a feed rate of 1200 lb per hr the grindability is

$$G = \frac{5.6 \text{ kw}}{0.6 \text{ tph}}\left(\frac{29.6}{W_{rm}}\right) = \frac{276}{W_{rm}} \text{ kw-hr per ton}$$

At a feed rate of 600 lb per hr, the grindability is

$$G = \frac{5.6 \text{ kw}}{0.3 \text{ tph}}\left(\frac{15.2}{W_{rm}}\right) = \frac{284}{W_{rm}} \text{ kw-hr per ton}$$

The small difference (3 pct), which is within the experimental limit of error, indicates that the grindability, G, is constant. Since the hypothetical optimum weight of retained ore was not determined, grindability can be given only in terms of W_{rm}.

The energy utilization factor, f, apparently decreases with finer grinding in the vibratory ball mill. For example, Table I shows that almost twice as much power is required to grind chromite from a size modulus of 67 μ to about 45 μ at a feed rate of 600 lb per hr than is required at 1200 lb per hr. The reason for this is that the energy utilization factor at 600 lb per hr is $\frac{5.1}{8.9}$ or 57 pct of the energy utilization factor at a feed rate of 1200 lb per hr. To increase the energy utilization factor and thereby reduce the total power for any grinding operation, the flow of material through the ball mill must be constricted in order to increase the amount of ore retained within the mill. The increased retention time should cause the product to be ground finer in accordance with Eq. 6.

As seen in Figs. 1 and 2, the size distributions are shifted laterally with expenditure of increased energy. In each case the value of α is 0.80. Considerable discussion has centered around the constancy of α.[1, 8, 38] If the size distributions are not carried into fine enough sizes, α will appear to vary. Had the data been plotted only to 400 mesh, the curves would have had the appearance of those in

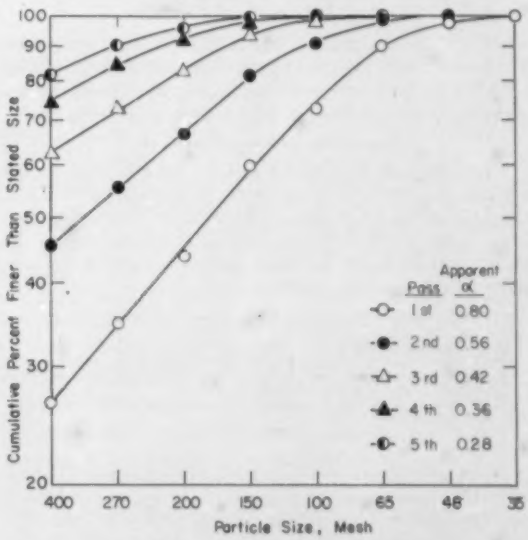

Fig. 5—Graph showing the apparent change in α when size distributions are plotted over a limited range only.

Fig. 5. As shown in Fig. 5, α would have had an apparent value of 0.80 after one pass through the mill but would have appeared to decrease to 0.28 after the fifth pass at 1200 lb per hr. The error would have been even greater if the data had been plotted only to −200 mesh.

Summary and Conclusions: The variable n hypothesis of Charles and Holmes can be extended to continuous grinding through the use of retention time as a measure of the fraction of the total energy which is useful for comminution. In the continuous vibratory ball milling of chromite, the equation for size reduction was found to have the following form:

$$(T_r)_p = A(k_p^{1-n} - k_f^{1-n})$$

where $(T_r)_p$ is the retention time at constant power input to the mill, A is a constant, k_p and k_f are the size moduli of the product and feed, respectively, and n is a constant for a given material and machine.

Experimentally, the size distribution of the products from continuous open-circuit grinding of chromite in a 15x15-in. vibratory ball mill were found to be shifted laterally with increased retention time. In each case the value of α, that is, the slope of the Schuhmann size distribution plot, was 0.80. The extent of the shift in size modulus depended on retention time, independent of a twofold change in feed rate. For the comminution of Transvaal chromite in the vibratory ball mill the value of n in the energy-size reduction equation was found to be 1.78, which lies about halfway between the values predicted by the Bond and Rittinger hypotheses.

In continuous ball milling the fraction of total energy which is useful for grinding depends upon weight of ore in the mill. Thus a statement of grindability for continuous grinding must include a factor that takes into account the efficiency of energy utilization, f, which is determined by the ratio of the weight of material retained in the mill at steady state, W_r, to the hypothetical optimum weight of retained material, W_{rm}. The grindability, G, of a material in a continuous mill is then:

$$G = \frac{P}{F} \cdot f = \frac{P}{F}\left(\frac{W_r}{W_{rm}}\right)$$

where P is the power input and F the feed rate. This statement permits comparison of grindabilities, which can be done only on a relative basis in the present work, since W_{rm} has not been determined.

This work was carried out in its entirety at the Metals Research Laboratories, Union Carbide Metals Co., Niagara Falls. The author wishes to acknowledge the assistance of J. J. Cunningham, J. M. Huse, and E. Laur for their part in making the experimental measurements.

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Discussion of this article sent (2 copies) to AIME before Jan. 31, 1960, will be published in Mining Engineering.

DISCUSSION

F. C. Bond *(Consulting Engineer, Allis-Chalmers Mfg. Co.)*—This research study is ably presented and discussed. The data are consistent and well arranged. However, this very consistency raises some questions.

The exact parallel extending down to 3 μ of the plotted size distribution lines shown in Figs. 1 and 2 is rather remarkable when compared with the plotted lines of many other products. Even when no grain size excesses or deficiencies are evident, a plot pattern more similar to Fig. 5 would be expected, with perhaps a flattening of the steeper lines below 400 mesh.

Experience with the Andreason pipette has demonstrated the difficulty of preventing partial flocculation at sizes of 10 μ and smaller, where the efficiency of the ordinary dispersing reagents seems to decrease. Progressive flocculation at the finer sizes could accord with the straight lines plotted. A check of the size distributions below 10 μ by microscopic grain counts or by some other method would be helpful.

Of course, it is also quite possible that the dust seals used did not completely contain these fine particles in the grinding circuit. The loss of fine particles, either by flocculation or as dust, would increase as the particle size decreased and could result in a straight size distribution line on a log-log plot. In any case, the whole argument of the article rests upon the amount of fine particles produced, and these determinations are subject to many errors.

The data presented are calculated according to the Third Theory in Table II, which accompanies this discussion. The 80 pct passing size P and the slope Er were obtained from Third Theory exponential plots[10] and[11] from Figs. 1 and 2, and the crack length Cr was obtained as shown in Ref. 11. Since the feed had an unnatural deficiency of fines it was necessary to estimate the P and Er values for an equivalent feed containing its natural fines. A natural feed would have been preferable.

For each pass at 1200 lb per hr the work input W is 9.33 kw-hr per ton, and 148 joules are expended per cubic centimeter of chromite ore, assuming that it has a specific gravity of 4. The ball voids at rest should contain about 68 lb of chromite ore.

The joules per centimeter of crack length produced are fairly consistent down to the last period at both feed rates. However, they are very erratic in the last period, whose P and Er values are most dependent upon the Andreason pipette measurements.

The work index values at 1200 lb are about twice as high as those expected for ordinary dry grinding, and they are still higher at 600 lb per hr. The low level discharge of the mill and the small amount of material retained in it during grinding apparently permit many wasted metal to metal contacts and increase both the work index and the joules per centimeter. Only 7.5 pct of the ball voids are occupied by 5.1 lb of chromite ore retained in the last two test runs.

This introduces a new variable into the author's calculation of the exponent n which will change its value. For if the retention time is decreased with a constant power input to the mill, then the amount of work done per time unit is also decreased because the proportion of nonproductive metal to metal contacts is increased by the decreased volume of material within the mill. The exponent n and the size moduli of the products will be affected by this factor as well as by the retention time.

Table II

Lb Per Hr, Pass No.	Feed Equivalent	1200 (1)	1200 (2)	1200 (3)	1200 (4)	1200 (5)	600 (1)	600 (2)	600 (3)
Slope (Er)	0.340	0.360	0.425	0.500	0.572	0.568	0.387	0.475	0.375
−80 pct size (P)	390	170	98	64	43.3	35	126	68.4	41.6
Cm per cc (Cr)	26.0	37.5	49.6	61.2	73.7	78.5	43.2	58.7	64.0
$Cr\sqrt{P}$	513	490	492	489	408	465	485	485	413
Ball voids occupied, pct		18.4	15.0	9.8	13.0	11.4	14.7	7.5	7.5
Unit process work index		35.8	38.5	38.6	34.6	54.9	48.5	58.7	54.7
Joules per cm		12.9	12.3	12.7	12.2	27.9	17.2	19.1	55.9
Cumulative work index		35.8	37.1	37.6	36.5	39.4	48.5	53.0	53.6
Joules per cm		12.9	12.5	12.6	12.5	14.1	17.2	18.1	23.4

The Charles-Holmes relationship is empirical and is based upon no specific mechanism or pattern of rock breakage. It is always possible that two different mechanisms are operating simultaneously, and that the Charles-Holmes variable exponent n expresses the balance between them. However, this exponent has been applied only to a size modulus value, or to only one point on the plotted size distribution curve. It is assumed in the present article that the slopes of the plotted lines are parallel as shown, so that the size modulus would be a valid expression of the actual work done in reduction if there is no grind limit effect.

It is contended in this discussion that the log-log size distribution plots are normally curved and divergent in both the coarse and extremely fine size ranges, so that the exponent n is not a correct evaluation of the work input required for reduction.

More studies similar to this one, with increased attention to the measurement of fine particle sizes and specific work input to the material being ground, will advance our knowledge in this important field.

REFERENCE

[11] F. C. Bond: *Confirmation of the Third Theory*. Presented at AIME Annual Meeting, San Francisco, 1959.

D. E. Fuerstenau (*author's reply*)—F. C. Bond has questioned the possibility of flocculation during the determination of size distributions of the −400 mesh material with an Andreason pipette. Obtaining complete dispersion is of course the main concern in using any method which utilizes settling rates for size analysis. In the present case, dispersion must have been quite complete because 48 hr after the sizing tests had been completed, fine particles were still in suspension. After this elapsed period, essentially clear water existed only for a depth of about 1 cm. In addition, some sizing tests were made in the Infrasizer (which can size chromite down to about 5μ) and size distributions obtained by the two methods were identical. As for dust loss in the grinding operation itself, every effort was made to make the operation essentially dust-free, and this type of loss should have been quite negligible.

One of the real controversies which seems to exist in the field of comminution appears to concern the nature of size distributions. Bond contends that log-log size distribution plots are normally curved and are divergent at both ends. It might be pointed out that the best way to obtain a size distribution plot that bends at neither end is to use Bond's technique of grinding in simulated closed circuit with a sieve. The author is of the opinion that the concept that size distribution plots appear to flatten with finer grinding results from not carrying the size distribution to small particle size. For example, in the case of the products from the five passes through the mill at 1200 lb per hr, the pipette analyses of the first four products were identical and the fifth was parallel but displaced toward a finer size, indicating that the bend in the curve occurs considerably below 400 mesh for this latter product.

If one were to carry out a series of batch grinding tests for a given period of time at constant power input but with varying amounts of material inside the mill, three distinct types of grinding conditions should exist. When the mill contains only a very small amount of ore, the size modulus of the product (k_1) depends upon grinding time only. If the amount of ore in the mill is increased but is still below that where metal-to-metal contacts occur, the product obtained will also have a size modulus of k_1. However, if enough ore is put into the mill, that of the energy put into the mill is wasted on metal-to-metal impact; then the product should have size modulus determined by the relation:

$$\frac{(t)\ (P)}{W} = \frac{C}{W} = Ak_2^{1-n}$$

where t is the grinding time, P is the power input, W is the feed weight, A, C, and n are constants, and k_2 is the size modulus of the product. If the amount of ore in the mill is increased until it impedes ball motion, this relationship no longer will hold and k_2 will rapidly approach that of the feed, since grinding will be retarded. These phenomena should be more apparent in a vibratory ball mill in which a large amount of power is put into a small machine. The conditions under which the present grinding tests were run were certainly in the range where the mill was underloaded and the shift in the size distribution plot depends upon time within the mill only at constant power input.

A statement of grindability should include an energy utilization factor f for both batch and continuous grinding, and in the case of continuous grinding this statement has the following form:

$$G = \frac{P}{F} \cdot f$$

where P is the power and F is the feed rate. Under conditions where metal-to-metal impact occurs $f < 1$, and as the amount of ore in the mill is increased f increases to 1. Under intermediate loading conditions, $f = 1$. As the loading becomes excessive, f decreases to zero.

HIGH-INTENSITY MAGNETIC SEPARATION OF IRON ORES

by O. E. PALASVIRTA

Close examination of most so-called *new* processes in mineral dressing reveals that they were conceived and developed a long time ago. High-intensity magnetic separation is no exception. Although its application in iron ore beneficiation seems new, in Germany the process has been commercially successful for almost two decades. High-intensity separators have long been standard equipment in the glass sand industry; they have also been used in concentrating some of the more unusual para-magnetic minerals.

The basic features of an induced-rotor, high-intensity magnetic separator were described by Désiré Korda in Paris in 1905,[1] and many patents have since been issued for improvements on the original design. Fig. 1 shows the basic design of an induced-rotor separator. Several U. S. manufacturers have been supplying induced-rotor separators for many years, but these are all devices of relatively low capacity, not suitable for treating such low-cost commodities as iron ore. On the other hand, two German manufacturers are offering induced-rotor separators of high capacity, both proven in the field.

The present investigation was prompted by the apparent success of the German installations and by the discovery of iron ores on this continent which may be amenable to high-intensity separation. The objective was to gain better insight into the underlying principles of separation in a high-intensity field and to use this knowledge in selecting or designing an optimum separator.

THEORETICAL CONSIDERATIONS

The well known low-intensity magnetic separators are, without exception, of the multiple horseshoe magnet type with more or less similar field shapes. It is therefore permissible to speak of their comparative strengths in terms of field intensity alone. However, proper understanding of the high-intensity magnetic separation process requires somewhat deeper analysis of the relationship between the magnetic field and the attractive force.

Contrary to a widely held belief, a magnetic field of parallel lines of flux exerts no attractive force on a magnetically susceptible particle, but merely aligns its poles parallel to the lines of flux. On the other hand, a non-uniform field attracts a magnetically susceptible particle in the direction of the converging lines of flux. Thus the force of magnetic attraction varies as the product of the field intensity and the field gradient:

$$F_m \propto H\frac{dH}{ds} \qquad [1]$$

As the induced-rotor magnetic separator is primarily intended for separating feebly magnetic materials, it is important that maximum attraction be attained. For the designer, then, the relationship between the magnetic field and the attractive force has the following implications:

1) Insofar as possible, the separation gap must be saturated with flux.

2) The rotor surface must be shaped to insure maximum convergence of lines of flux toward the rotor.

3) The primary pole face (opposite the rotor, on the other side of the separation gap) must be shaped so that the lines of flux do not diverge from it at any location in the effective separation zone.

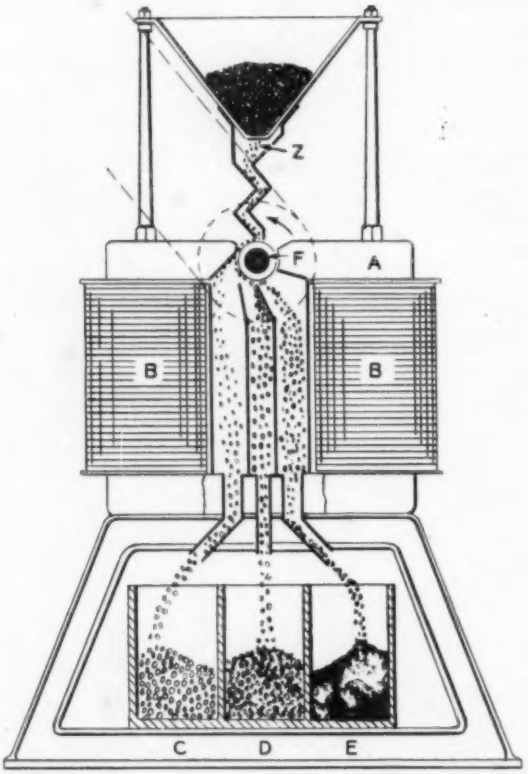

Fig. 1—Early type of high-intensity induced-rotor magnetic separator. A. Magnet poles. B. Coils. C. Tailing. D. Middling. E. Concentrate. F. Rotor. Z. Feed device.

The actual attractive force of the rotor, and its critical speed, can be calculated as shown by Runolinna,[2] provided that the true flux density, the field gradient, and the magnetic susceptibility of the mineral can be measured with sufficient accuracy. The irregular shape of the rotor surface makes flux measurements difficult, but it can be done if a suitable gaussmeter is available (see Fig. 2). Calculations by the author, and comparisons with the centrifugal force exerted by the rotor, indicate that the force pinning a hematite particle to the rotor is of the same order of magnitude as the force holding a

O. E. PALASVIRTA, Member AIME, is Development Engineer, Oliver Iron Mining Div., U. S. Steel Corp. TP59B73. San Francisco Meeting, February 1959. AIME Trans., Vol. 214, 1959.

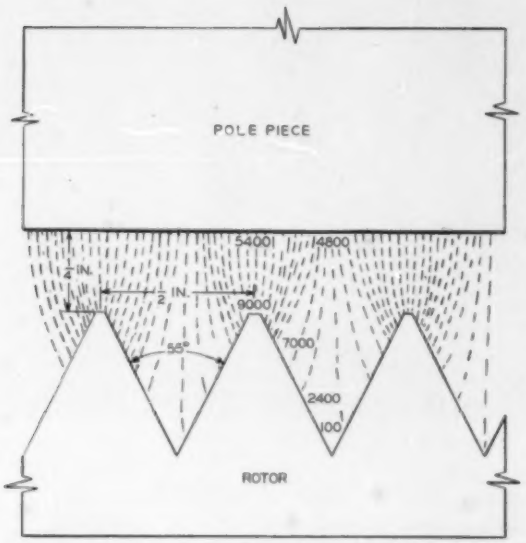

Fig. 2—Relative flux densities (gauss) and direction of flux in separation gap (triangular ridges on rotor). With ¼-in. ridges and ¼-in. gap the mean flux density is a great deal higher but is difficult to measure locally.

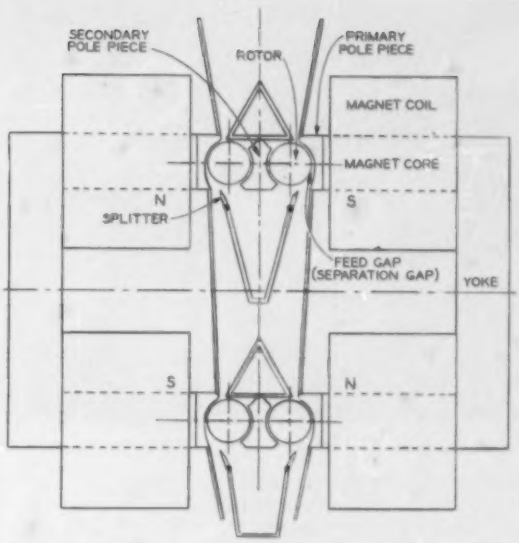

Fig. 3—The above sketch shows the magnetic circuit of a two-stage, double-rotor, high-intensity separator.

magnetite particle to a conventional low-intensity separator drum. It is important to note, however, that this pinning force (exerted when the particle is in contact with the rotor) is many times greater than the attractive force, say, in the middle of the separating gap.

BASIC DESIGN OF IDEAL SEPARATOR

The Magnetic Circuit: The critical nature of the magnetic circuit in an induced-rotor separator may be illustrated by a familiar textbook example dealing with magnetization of an iron ring. After the amount of magnetization corresponding to a given excitation is determined, a small gap is cut into the ring. Even if the width of the gap is negligible compared to the circumference of the ring, the magnetic reluctance of the system will be increased as much as ten times and the exciting current must be made tenfold in order to maintain the original degree of magnetization. Since any induced-rotor separator has at least two air gaps, on both sides of the rotor, and since the average intensity desired in the separation gap is about 20,000 gauss, the excitation coils must be massive as compared to the coils of a low-intensity separator. It is also known that magnetic flux tends to leak from sharp angles in the circuit. Thus the most effective location of the magnet coil is immediately behind the primary pole piece, as shown in Fig. 3.

Fig. 3 also illustrates two other important features of the proposed ideal separator. The distribution of dry feed, generally a difficult problem, is alleviated by arranging two rotors side by side so that they can treat a common feed flow. Since effective separation usually requires at least one cleaning pass of the tailing from the first pass, the separator is made into a two-stage machine by installation of another pair of coils and rotors in the lower half of the magnetic circuit. This also results in more economical use of iron, as the circuit would have to be closed with heavy members in any case.

Shape of Pole Pieces and Rotor Surface: The requirement that the attractive force must be directed toward the rotor affects the shaping of both pole pieces and the rotor surface. Fig. 4 presents profiles of eight pole pieces tested. A short description of each will help in understanding the final choice of shape.

Profile *A* in Fig. 4 was initially chosen with the idea that the sharply receding pole face would provide room for a high-speed trajectory of tailing particles which would prevent their rebounding to the concentrate flow. However, both separation efficiency and capacity were poor. Field intensity measurements then indicated that considerable flux was bypassing the narrowest separating zone by bridging, via the top of the rotor, between the sharp upper edges of the primary and secondary pole piece. A changeover to profile *B* decreased bridging, but performance remained poor.

Attempts at higher feed rates by free fall through the separation gap were not successful but showed that profile *D*, with a straight face, was superior to profile *C* with a convex pole face. The first good

Table I. Selected Data from High-Intensity Magnetic Separator Testing

Feed Sample	Mesh, 100 Pct Passing	Number of Passes	Feed Rate to First Rotor, L.T. Per Hr Per Ft	Concentrate Wt, Pct	Concentrate Fe, Pct	Concentrate SiO_2, Pct	Fe Rec., Pct
Coarse-grained specular hematite ore from Quebec	14	4	3.6	53.1	67.5	3.0	97.5
Coarse-grained specular hematite ore from Quebec	14	3	4.5	50.5	68.3	2.0	94.0
Coarse-grained specular hematite ore from Quebec	14	3	5.0	52.1	66.7	4.1	95.7
Coarse-grained specular hematite ore from Quebec	14	3	4.5	51.2	66.6	4.2	91.5
Spiral feed from Mesabi Range washing plant	20	4	1.9	33.0	58.4	9.2	79.3
Fine-grained specular hematite ore from Quebec	65	4	2.9	64.4	44.6		95.4

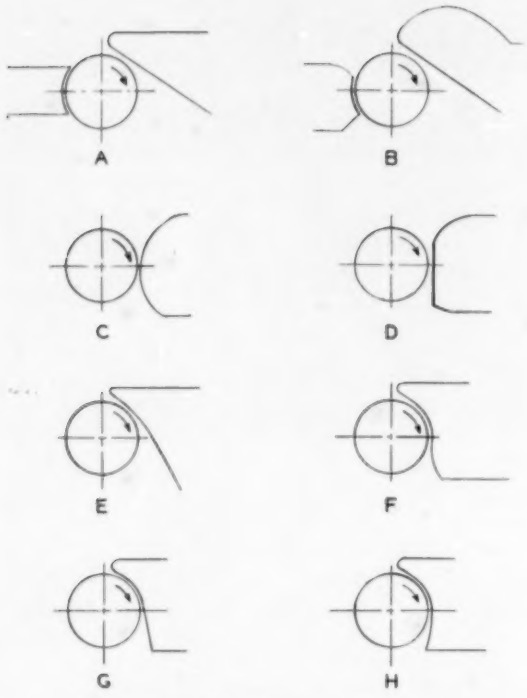

Fig. 4—Profiles of primary pole pieces.

results were obtained with the concave pole face depicted in sketch *E*, and very successful operation was finally attained with profile *H*.

It was concluded that the primary pole piece must provide the longest possible zone of high intensity as well as a consistently concave surface facing the rotor. The importance of consistently concave surface was further illustrated by the shapes of profiles *F* and *G*. The lower portion of pole piece *F* was made slightly convex by mistake, with the result that there was no clear distinction or empty zone between the tailing and concentrate flows. The situation was corrected by machining the convex surface straight as shown in sketch *G*.

Fig. 5 is a more detailed sketch of the preferred shapes and positioning of the pole pieces. The concave face of the primary pole piece has a cylindrical upper half and an involute lower half. The secondary pole piece hugs the rotor tightly but does not provide close edges that would serve to bunch up the flux from the upper and lower edges of the primary pole piece.

The shaping of the rotor surface offers at least as many possibilities as that of the pole pieces. Only two shapes will be discussed here.

Fig. 6A shows a rotor with square teeth in longitudinal cross-section. The valleys in this construction may or may not be filled with nonmagnetic material (flattened brass wire, for example, if the groove is a spiral). The square teeth converge the lines of flux toward the sharp edges, creating an attractive force directed toward the rotor surface, but tests with this kind of rotor gave mediocre results.

According to Derkatch,[8] triangular teeth or ridges, as shown in Fig. 6B, produce the maximum attractive force. Work at Oliver Iron Mining's research laboratory confirms this. Derkatch also claims, however, that the desired pitch or distance between the ridges is dependent on the particle size

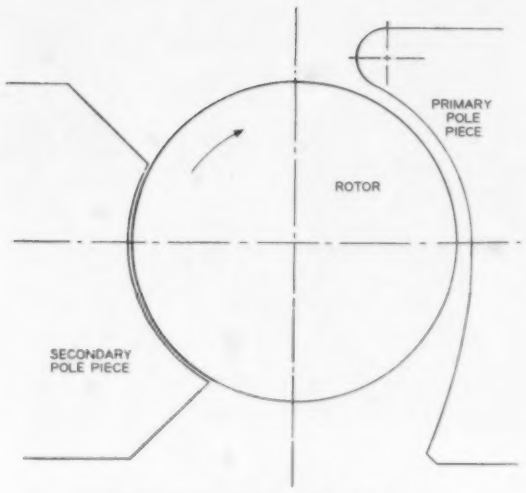

Fig. 5—Profiles of pole pieces.

treated. In this respect tests made in the present investigation have given conflicting results. It may be that the work mentioned by Derkatch was done with non-spiraling ridges on the rotor, whereas Oliver's laboratory rotors had a spiraling ridge. The inertia of the particles falling in the valleys between the ridges causes them to travel more slowly than the rotor surface, and while they are delayed they are caught by the sidewise-moving areas of strong attraction near the crests of the spiraling ridges.

Drives, Feeders, Feed Chutes, and Splitters: Capacity of the separator and grade of concentrate depend on how fast the rotor may be operated before the centrifugal force exceeds the magnetic attraction force. With a 4-in. rotor, speeds of 200 to 450 rpm have been found to be feasible. Optimum speed seems to vary according to feed rate or stage of separation; consequently, variable-speed drives should be specified for each stage.

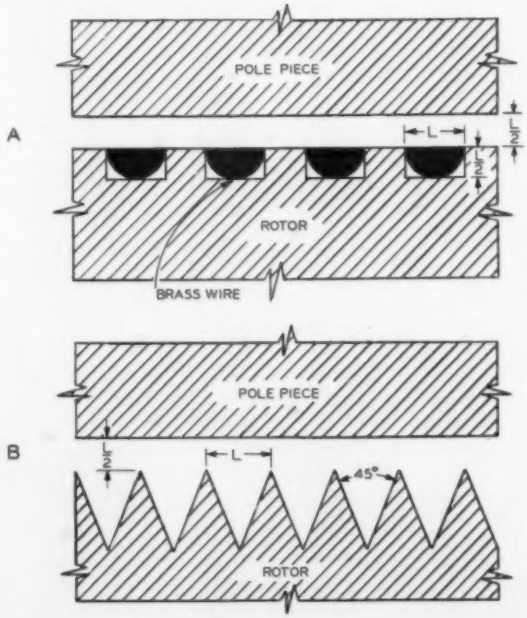

Fig. 6—Illustrated above are two types of rotor surface and their position with respect to the pole face.

Fig. 7—General arrangement of the separator used.

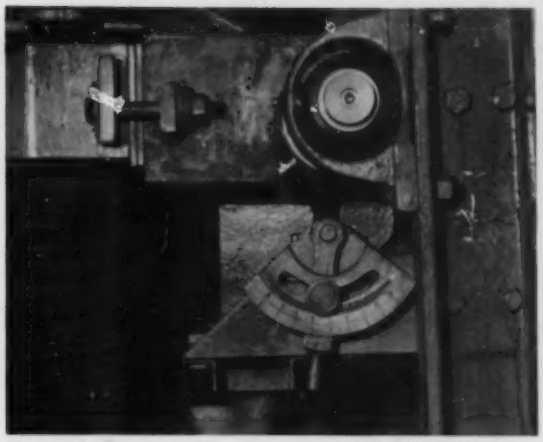

Fig. 8—Note separation of concentrate and tailing flows.

The design of feed chutes permits considerable freedom, but care should be taken that they provide an unhindered feed flow. There should be no problems in positioning the product splitters, but they should be placed where they can be easily observed and readjusted while the separator is in operation.

OPERATION OF SEPARATOR

Rebounding of tailing particles from the pole face into the concentrate is a serious problem affecting purity of product. This tendency will naturally increase as the rotor is speeded up to gain improved capacity. A fortunate circumstance was discovered, however—as feed rate was increased to the maximum the separator could receive, the stream of particles in the separation gap became so dense that contamination of concentrate by rebounding gangue ceased, although the particles still had considerable freedom of motion relative to one another. What might be called *choke feeding* thus turned out to be an important requirement for good separation efficiency as well as for capacity.

As the distance between the triangular ridges of the rotor is increased, without means of simultaneously increasing the excitation, the effective width of the separation gap, and consequently the reluctance, also increases. Correspondingly, the mean field intensity decreases. However, the remaining field is now divided between fewer ridges and, up to a point, the attractive force may actually increase. In testing at Oliver this was observed when the distance between the ridges was increased from ⅛ to ¼ in. The increased attractive force also seemed further to eliminate contamination of concentrate by rebounding gangue, regardless of rotor speed or whether the separator was choke-fed or not. Apparently choke feeding is essential only when the attractive force is relatively weak.

Table II. Combined High-Intensity Magnetic and High-Tension Separation Test on Fine-Grained Specularite from Quebec

	Wt, Pct	Fe, Pct	Fe Rec., Pct
High Tension Separator Concentrate	33.4	64.6	73.2
High-Tension Separator Tailing	23.5	24.8	
High-Intensity Magnetic Separator Tailing	43.1	4.8	

Selected Examples of Performance: The close-ups in Figs. 7 and 8 show the main features of the separator used in the testwork described. It should be noted that the excitation coil is smaller than used on most high-intensity separators and that there is no means of resaturating the core after the reluctance of the circuit has been increased past a certain value of widening the gap. The following selected test results should be considered, therefore, with the understanding that they are not the ultimate attainable by the high-intensity process.

Fig. 9 presents a comparison of two rotors, one with a ⅛-in. pitch and another with ¼-in. pitch. The coarser rotor did better in three passes than the finer rotor in five, although the mean field strength was considerably lower.

Table I offers additional selected test data. Results with a coarse-grained specularite ore from Quebec are excellent. Those obtained with sized Mesabi hematite (feed to the spiral section of a Mesabi Range washing plant) are considerably poorer, but concentration of Mesabi hematites did not fall into the scope of this investigation, and more exhaustive testing may produce better results. Those shown here about equal the average spiral performance. A difficult problem was presented by some fine-grained specularite ores from Quebec; a clean tailing of considerable weight could be produced, but concentrate grade remained poor. It was found that these ores contained low-grade middling particles of higher magnetic susceptibility than the liberated hematite itself. Superficially these middling particles resembled quartz, but microscopic examination revealed many small inclusions of iron oxide. The relatively high susceptibility of these middling particles is somewhat of a mystery because a chemical analysis showed only 0.6 pct Fe^{++}. A high-tension separator was *blind* to this middling and was able to make a high-grade product from the high-intensity concentrate. Table II shows results from a combination high-intensity—high-tension test.

Some Commercial High-Intensity Magnetic Separators: Schematic views of commercial types of high-intensity separators are given in Fig. 10. It should be noted that four of these separators, *A-D*, are now or have been employed successfully in concentrating iron ore in Germany. Sketches *E* and *F* feature separators of American design, so far exclusively employed in concentrating nonferrous minerals. In the following discussion the general layout of these separators is examined in the light

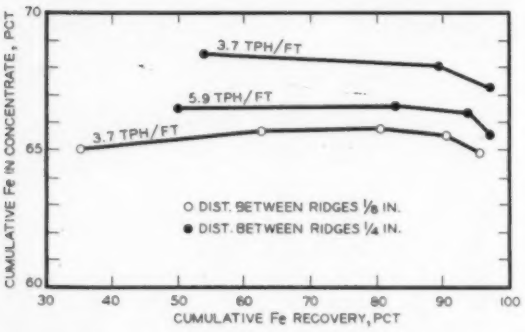

Fig. 9—Effect of rotor pitch on separator performance. Feed: coarse-grained specular hematite ore from Quebec.

of experience from laboratory testing or knowledge of magnetic circuits in general.

Separator *A* evidently was a forerunner of *B* and, as far as the writer knows, is no longer being built. Scant performance data are available, and the only comments would concern the need of apportioning feed between the two rotors and the lack of a second stage.

Both these limitations are overcome in the design of separator *B*, reported to be of high capacity and offering the advantage of two stages built into one circuit. Two features are viewed with some criticism, however:

1) The field between the two rotors is reduced by flux leakage from the secondary gaps between the rotors and the pole pieces.

2) The rotors weaken each other's field gradients. (They resemble a system consisting of a rotor and a primary pole piece with a convex face). Tests show that this has an adverse effect on recovery.

It is fair to assume that separator *C*, in turn, evolved from separator *B*. Item 1 in the preceding criticism still applies to this separator, but otherwise it must be considered an improvement. A common pole piece has been inserted to present a concave face to both rotors. Thus the field gradients have the right sign in all parts of the separation gaps.

In separator *D* the second stage has been eliminated and a parallel stage added. Reportedly, this was done at no expense of total capacity. On the other hand, this arrangement avoids the situation where the feed rate to the second stage is set by the output of the first stage. In the author's experience, however, this difficulty can be eliminated by proper design of the rotor surface as was described above.

The rotor-pole piece arrangement in sketch *E* generally follows the principles of preferred design except that the sharp upper edges of the pole pieces are too close to each other. Laboratory experiments show that in this arrangement the flux tends to bridge through the upper portions of the system, leaving the field weak in the rest of the separation gap. This would affect the separator's capacity adversely.

Sketch *F*, finally, presents the common, back-to-back layout favored by several American manufacturers of these separators. Generally a dummy pole, as shown, is included for pre-removal of highly magnetic minerals that might clog the high-intensity gaps. Compared to the ideal layout presented earlier, this design does not place the coil most effectively. The ideal separator also handles a single flow of feed, twice as large as the back-to-back separator.

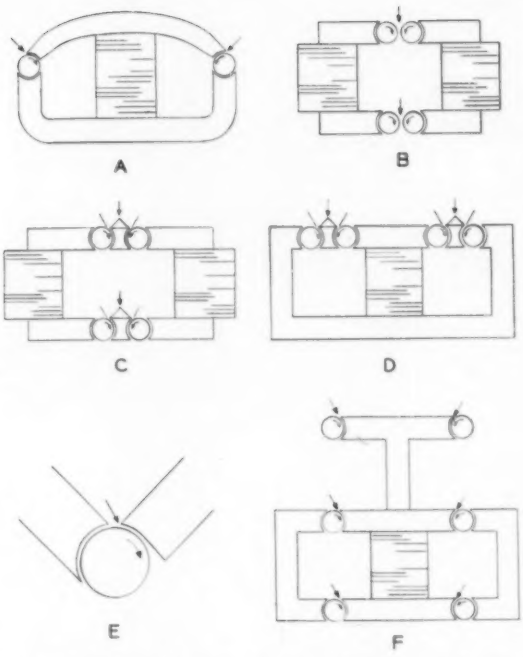

Fig. 10—Schematic view of several commercial types of high-intensity, induced-rotor magnetic separators.

CONCLUSION

There is no doubt that properly designed high-intensity separators will find wider application in concentrating iron ores. Being a dry process, high-intensity separation offers particular advantages whenever water supply is limited. But a thorough knowledge of the ore is needed before the process can be considered; some ores of seemingly simple mineralogy cannot be concentrated by this method.

The author expresses thanks to R. J. Morton, R. L. Bennett, and M. F. Williams, under whose supervision the present investigation was made. He also acknowledges, with appreciation, the valuable contribution by J. R. Andreachi of the Oliver research staff.

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Discussion of this article sent (2 copies) to AIME before Jan. 31, 1960, will be published in MINING ENGINEERING.

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REDLETTER DATES --- February 14 to 18

• *For the AIME Annual Meeting in New York, SME headquarters will be the Statler-Hilton Hotel, indicated on the photograph of New York's skyline by the arrow head. For an outline of the SME technical program, to-date, and social events during the meeting, turn to the program section on page 1222. Abstracts of SME papers, arranged according to Division, begin on page 1223. If your wife is coming with you, be sure to show her the story on page 1251—an outline of WAAIME programming for the week. Star below the Empire State Building locates SME's 39th St. office. If you have time, take a trip to 49th St. and UN Plaza for a look at the location of the new United Engineering Center, erection of which is to begin soon—1961 is the target date for occupancy.*

1960 Dues Bills

Notice is hereby given that dues for the year 1960 are payable Jan. 1, 1960, as follows. Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12, and thereafter, $17; Student Members (including an annual subscription to a monthly journal), $4.50.

Dues bills were mailed in early November. Prompt payment will assure uninterrupted receipt of the publications desired in 1960. If, for any reason, a bill is not received within a reasonable time, please notify AIME.

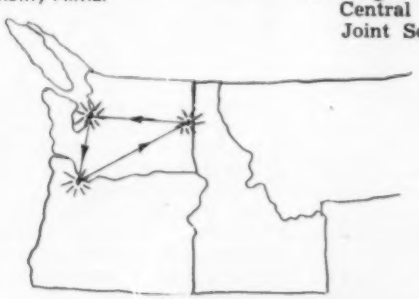
The regular Annual Business Meeting of AIME will be held on Tuesday afternoon, February 16, 1960, following the All-Institute Session in the Statler-Hilton Hotel, Grand Ball Room, during the Institute Annual Meeting in New York.

Mineral Information Section Begins on Page 1192

Meetings—Future, Page 1250
AIME Minnesota Section and University of Minnesota Mining Symposium
AIME Pacific Southwest Regional Metals and Minerals Conference

Meetings—Past
Central Appalachian Section, 1251
Joint Solid Fuels Conference, 1254

Newsletters . . .
• Coal page 1255
• Rock in the Box page 1253



Technical Program Starts on Page 1252

Proposals for Membership
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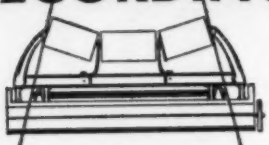

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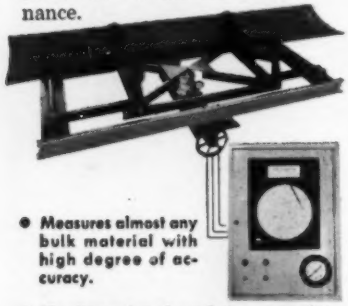

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Geological Society of America Holds Convention

Sir Edward Bullard, Adolph Knopf, and Jack L. Hough, left to right, were awarded the Geological Society of America's highest honors at the annual dinner in the Penn-Sheraton Hotel ballroom on November 3 in Pittsburgh. Dr. Knopf was the penrose Medalist; Sir Edward Bullard was awarded the Arthur L. Day Medal; and Dr. Hough received the Kirk Bryan Award. The award dinner was the highlight of the largest convention in the Society's history with more than 2200 members and guests attending the meeting.

Southwest Metals And Minerals Plans 1960 Space Age Conference

Plans for the Southwest Metals & Minerals Conference are maturing rapidly, according to Henry T. Mudd, the chairman of the general committee. In addition to the regular conference dates of April 21 and 22, 1960, field trips are scheduled for Saturday, April 23. The meeting will convene at the Ambassador Hotel in Los Angeles.

The committee has been fortunate in obtaining Albert C. Hibbs, chief of the Division of Space Sciences at Jet Propulsion Laboratories, as the banquet speaker for Thursday, April 21. Dr. Hibbs' address will amplify the conference theme of "Metals and Minerals for the Space Age."

Host and co-sponsor of the conference is the Southern California Section of AIME. The Rock Products Assn. of Southern California will collaborate with the Section.

The program will emphasize papers on energy sources for fuels materials for the space age, special minerals for ground installations, a symposium on boron, a rocks products symposium, a mining session, industrial minerals, and related data.

Ladies' registration and programs are in advanced planning stages. Interesting events have been promised for their enjoyment.

The following members have been selected to act as chairmen of the principal committees: H. T. Mudd, chairman of the general committee with H. Mulryan, Sr., and Walter M. Pollit as vice chairmen, Clarence Six as treasurer, and Jack L. Taylor as secretary; Lauren A. Wright, liaison agent; Donald Carlisle, chairman of student affairs; Mrs. Harold Clark, chairman of ladies activities committee, with Mrs. Richard Jahns as vice chairman; W. H. Crutchfield, Jr., chairman of the registration committee; G. D. Dub, chairman of finance; J. L. Goheen, publicity; Richard Jahns, in charge of field trips; D. L. Martlett, chairman of general arrangements; Franklin J. Weishaupl, chairman of program committee; Allen Pollock, chairman of the chamber of commercial registration; and John E. Wilson, advisory.

Minnesota Symposium Will Follow AIME Meet

The 1960 University of Minnesota Mining Symposium will follow the Minnesota Section meeting on January 11 in Duluth. The two meetings will discuss the same theme: *Lake Superior Iron Ores and the American Economy.*

Robert J. Linney, Section chairman, has invited all symposium registrants to attend the AIME meeting. L. C. Michelon, consultant for Republic Steel Corp., will speak at the two AIME sessions.

Then on Tuesday, January 12, the symposium will convene at the Norshor Theater. Three morning papers will cover iron ore reserves, current developments in New Quebec, Labrador, and South America. Speakers so far lined up are Robert Lloyd and Gordon A. Gross.

In the afternoon John S. Wilbur will discuss the competitive position of Lake Superior iron ores and a panel on desirable characteristics of iron ore for furnace use will be led by Dwight C. Brown.

On Wednesday, Bay Estes, John D. Sullivan, and R. H. Whitney will present papers on the topics of substitutes, automation, and a general economic summary.

Registration should be made in advance for the Section meeting and symposium. Please write to: Director, Center for Continuation Study, University of Minnesota, Minneapolis 14, Minn.

Joint Meeting Held At White Sulphur Springs

The AIME Central Appalachian Section and the West Virginia Coal Mining Inst. held their annual meeting on October 30 and 31 in White Sulphur Springs, W. Va. The Greenbriar Hotel was the headquarters.

Registration began early Friday morning before the first technical session. E. M. Spokes and J. B. Herring were co-chairmen for the panel discussion on continuous mining methods. U. A. Cobb, superintendent at Kopperston mine, W. Va., gave the first paper entitled *Comparison of Continuous Mining and Mobile Loading in Same Mine Under Similar Conditions.* J. S. Whittaker, vice president at Pittsburgh Coal Co., Library, Pa., spoke on *Complete Extraction With Continuous Mining Machines* and J. W. Heimaster of Union Carbide Olefins Co. lectured on *Improved Techniques in Mining from the Outcrop With Continuous Mining Machines.* These papers were followed by discussions presented by Richard F. Wesner of Boone County Coal Corp.

R. Glenn Lazzeil, president of the West Virginia Coal Mining Inst., presided at the luncheon for the men in the Mural dining room. He introduced the guest speaker, Tom Pickett, who is executive vice president of the National Coal Assn.

In the afternoon D. A. Zegeer and Roland C. Luther were co-chairmen. D. B. Bonebrake, Pocahontas Land Corp., told about *Forest Management for Coal Properties.* C. W. Porterfield, assistant mechanical engineer, and Guy N. Haynes, superintendent of preparation plants for Pocahontas Fuel Div. of Consolidation Coal Co., presented *Fine Coal Cleaning and/or Water Clarification.* Then Henry F. Hebley presented a discussion, and J. J. Slomer, chief hydraulic engineer for Goodman Mfg. Co., closed the session with his paper on the *Present Status of Hydraulic Mining Applications.*

The two groups held business meetings after this session before cocktails and dinner Friday evening. Carel Robinson, chairman of the Central Appalachian Section, presided at the dinner in the ballroom, and Charles E. Lawall, vice president of the Society of Mining Engineers, acted as toastmaster. The speaker for the event was Joe E. Moody, president of the National Coal Policy Conference in Washington, D. C.

On Saturday morning a final session was held with Richard M. Wesner and E. M. Pace as co-chairmen. R. E. Joslin, Clinchfield Coal Co., discussed *Highlights (Moss No. 3 Preparation Plant)* and E. H. Roberts, chief mining engineer for Inland Steel Co., spoke on *Voltage and Productivity on Operating Sections.* R. D. Greer of Joy Manufacturing Co. gave the discussion that followed and Earl R. Maize, mining health and safety engineer for the U. S. Bureau of Mines, wound up the conference with his paper on *Recent Experiments in Cementation of Mine Roof with Polyester Resins.*

The ladies had their program which included a tour of the Greenbrier, luncheon at the Golf and Tennis Club, bridge and tea, plus cocktails and dinner with the men.

Joint committees planned the conference, with Fred Toothman head of the program committee and C. T. Holland in charge of arrangements. Their committeemen and the wives who helped deserve a vote of thanks.

Banquet scenes feature the head table on the left with speakers and officers smiling for the camera. W. J. Skewes is seen at the far left next to Mrs. and Mr. Carel Robinson, the chairman of the Central Appalachian Section. Dr. and Mrs. C. E. Lawall, SME vice president, are next and Joseph E. Moody, president of the National Coal Policy Conference and speaker for the banquet, is in the center. Mrs. and Mr. S. Dunlap Brady and E. M. Pace complete the table. On the right running clockwise from the corner are Mr. and Mrs. J. S. Whittaker, D. C. Ridenaur, C. T. E. Bearsley, C. H. Irwin, and J. C. Fox. Mr. Whittaker was a session speaker.

Plans Are Shaping Up for WAAIME's Share of the Institute Annual Meeting

The Woman's Auxiliary of AIME has arranged a thorough program for the wives who attend the Annual Meeting in New York from February 14 to 17. Mrs. Lyman H. Hart is chairman of the entertainment committee and is being assisted by C. P. Pollock, vice chairman. Mrs. Howard Pyle and Mrs. Joseph Gillson are honorary chairmen.

First in importance on the agenda is registration at the Hotel Statler from 1 to 5 pm on Sunday, February 14. Mrs. Edward Robie, chairman, will be on hand to collect the $2 fee. Mrs. Domingo Moreno is membership chairman and Mrs. J. R. C. Mann is chairman in charge of tickets. The luncheon-fashion show will cost $6.50 and the buffet luncheon will be $3. In order to purchase tickets for luncheons, registration badges must be shown, so be sure to register first.

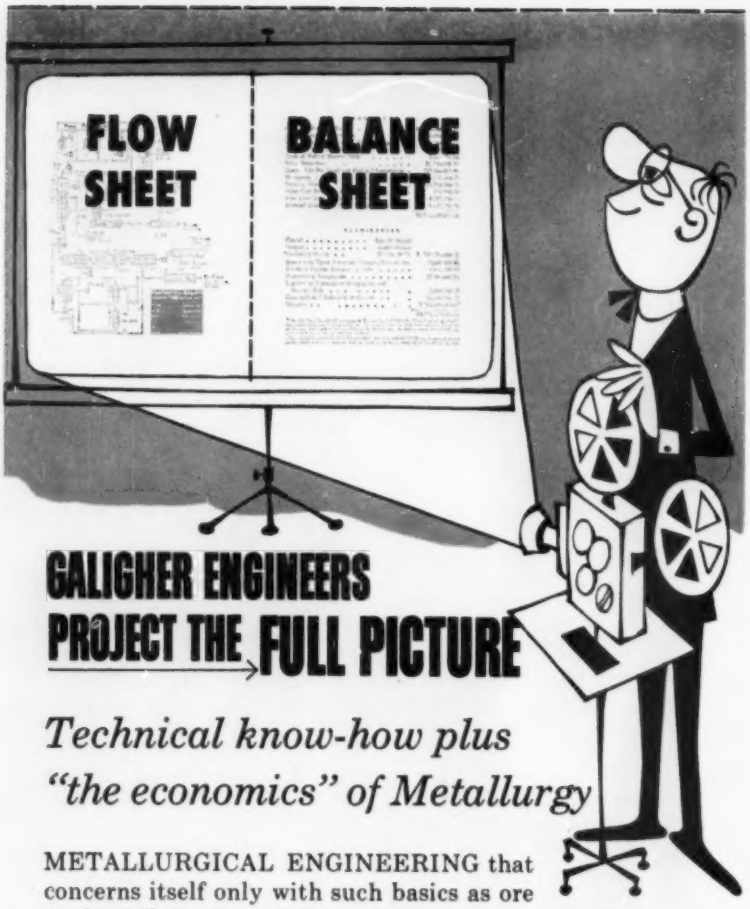
At the information desk Mrs. V. D. Perry, chairman, will supply data on the Cloisters, the Guggenheim Museum, the Steuben Glass exhibit, the Museum of Modern Art and the Metropolitan Art Museum. The Hospitality Room will also be open on Sunday from 1 to 5 pm.

Registration will continue on Monday morning from 8 to 5 and a coffee hour will begin at 9 with Mrs. Michael Haider, chairman, on hand to greet members and wives on behalf of the New York Section of WAAIME. The Welcoming Luncheon will begin around 11:30 at the Statler, with Mrs. Felix Wormser and Mrs. Robert Weeks as hostesses. After a free afternoon for sightseeing, a cocktail party will be given at 6 in the evening.

Tuesday will be a busy day for convention wives, beginning with a Round Table Meeting in the Baroque Suite of the Plaza Hotel at 9:30 with Mrs. Stephen Krickovic presiding. The luncheon and fashion show will be held in the Grand Ballroom of the Plaza and Mrs. Andrew E. Beer, WAAIME President, will give a welcoming address. Mrs. C. P. Pollock is chairman, and Mary Alice Rice is fashion show coordinator and commentator. Back at the Statler in the evening there will be an informal dance at 9 pm, with Mrs. Harris Grose and Mrs. Edward Eakland as hostesses.

On Wednesday the WAAIME Annual Meeting will convene in the Baroque Suite of the Plaza at 9:30 with Mrs. Beer presiding. A Buffet luncheon will follow and a style show called Spring Forecast by B. Altman will highlight the afternoon, directed by Jane Horton and Miss

(Continued on page 1256)



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Pacific Northwest Metals and Minerals Conference Program

THURSDAY, APRIL 28, AM

9:00 am **Refractory Applications in the Aluminum Industry**

Charles McVicker, *Chairman*

Evaluation of Commercial High Aluminum Brick for Aluminum Melting Furnaces: *J. E. Lorenz*, Kaiser Aluminum & Chemical Corp.

Refractories for the Carbon Brake: *Wes Leuking*, A. P. Green Fire Brick Co. Paper from Harbison-Walker Refractory Co.

9:00 am **Geology**

Fay W. Libbey and Lloyd Staples, *Chairmen*

Geology of Lakeview, Oregon, Uranium Area: *Norman L. Peterson*, State of Oregon Dept. of Geology and Mineral Industries.

The New Mining Laws: *Irving Rand*, attorney.

Drilling of an Alaskan Sulphide Deposit under a Glacier: *John McKee*, Freemont Mining Co.

Boron Deposits in Oregon: *F. W. Libbey*

9:00 am **Metals Branch Extractive Metallurgy—Process Metallurgy Developments**

Harry Czyzewski, *Chairman*

Direct Reduction Process for Pig Iron: *H. L. Lownie*, Battelle Memorial Inst.

Strategic-Udy Process: *Murray C. Udy*

Nickel Smelting at Riddle, Oregon: *D. Vidensky*.

Aluminum Extraction from Ferruginous Bauxite, USBM paper.

THURSDAY, APRIL 28, PM

12:00 pm **Luncheon**

Speaker: *E. C. Babson*, manager of operations, Canadian Div., Union Oil Co.

1:30 pm **Refractory Applications in The Aluminum Industry**

Charles McVicker, *Chairman*

Silicate Carbide Applications, paper from The Carborundum Co.

Paper presented by Holding Furnace Manufacturer

Paper presented by University of Washington or U.S. Bureau of Mines Ceramic Laboratories

1:30 pm **Geology**

Fay W. Libbey and Lloyd Staples, *Chairmen*

Pacific Northwest Oil and Gas Exploration: *Robert Deacon*,

(Continued on page 1256)

ROCK IN THE BOX

Mining & Exploration Division

Robert J. Linney Is Awarded the William Lawrence Saunders Medal for 1960

One of the Institute's major honors, the William Lawrence Saunders Gold Medal, has been awarded to Robert J. Linney, the executive vice president of Reserve Mining Co. Mr. Linney will receive this award "for administrative leadership and aggressive determination in bringing into successful commercial operation mining and beneficiation of taconite iron ore." Presentation will be made at the AIME Banquet during the Annual Meeting in February in New York.

The award was established in 1927 through a gift from Mr. Saunders, former president of AIME. It recognizes distinguished achievement in mining other than coal.

Robert J. Linney was born in old Forge, Pa., in the fourth generation of a mining family. His grandfather was a Welsh miner who came to the United States from the iron mines of England. His father started in the coal mines of Pennsylvania as a slate picker, and Bob began his mining career at the age of 12 in the Adirondacks. He was educated at Worcester Academy and Yale University, studying engineering, and took his first job as mining engineer at the properties that his father had developed at Lyon Mountain, N. Y., for the Chateaugay Ore and Iron Co.

Soon he became level foreman, then superintendent of concentrating and sintering, and in 1937, general manager. When Republic Steel Corp. acquired the properties in 1939, he was named district manager.

His avid hobby of bobsledding shared in bringing him honors during this period and he was nominated the No. 1 bobsled driver for 1939, with his team barely missing the 1940 Olympics because of the war.

At that time he made the choice between bobsledding and mining,

and devoted himself solely to his career with his appointment as general superintendent for Republic Steel at Port Henry, N. Y. There he advanced through other management positions until named district manager of the Port Henry operations in 1945.

In 1950, with his background in processing of magnetite and his highy successful managerial career, Mr. Linney had an important role in the planning and selection of complicated mining and processing equipment in his new position as manager of operations for Reserve Mining Co. In this capacity he was sent to the taconite operations at Babbitt and Silver Bay, Minn., that were owned by Republic Steel Corp. and Armco Steel Corp.

After six years in this position, Mr. Linney was elected vice president in charge of operations. In 1958 he became executive vice president and a member of the executive committee of Reserve.

In addition to his contributions to the field of taconite processing as an executive, Mr. Linney is the author of numerous technical papers and holds patents used in mining, agglomeration, and beneficiation. The Linney magnetic separator now used at Silver Bay is one example of his patents.

Outside of the mining industry, Robert Linney is well known in community affairs and sports, managing amateur and semipro baseball teams and joining clubs in cities that he frequently visits. He is also a former president of the Port Henry Chamber of Commerce. But most of all, he is recognized as one of the natjon's distinguished leaders in his field.

R. V. Williams Awarded The Frank J. Tone Award

Reginald V. Williams, president and director of research of the Williams Gold Refining Co. Inc., Buffalo, has been named as recipient of the 1959 Frank J. Tone Medal Award. The medal is awarded annually by the Niagara Frontier Section in honor of Frank J. Tone, pioneer industrialist.

Mr. Williams has been a leader in research and development of precious metals metallurgy for the dental profession and for industry. The award was presented at the annual Award Meeting on November 18 at the Hotel Stuyvesant in Buffalo by W. W. Stevens, chairman.

EDITOR

Address news items to:

John W. Chandler, American Metal Climax Inc., 61 Broadway, New York 6, N. Y.

These smiling wives and WAAIME members were photographed between stops in their busy schedule which included a cruise.

Joint Solid Fuels Conference Convened in October

The twenty-second annual Joint Solid Fuels Conference was held at the Netherland Hilton Hotel in Cincinnati on October 27 to 29. It was co-sponsored by the Coal Division of AIME and the Fuels Division of the American Society of Mechanical Engineers, in cooperation with the AIME Ohio Valley Section and the ASME Cincinnati Section.

Technical advancements in the mining, preparation, and use of coal was the major theme of the conference. This was developed in papers presented at technical sessions and in the luncheon speech on *Inventiveness and Human Betterment*, presented by A. A. Potter, president of Bituminous Coal Research. W. C. Bissmeyer, chairman of the Cincinnati Section, ASME, presided at this first luncheon on Wednesday, introducing Dr. Potter.

Homer H. Lowry, left, beams with pride as he is presented the Percy Nichols Award by D. R. Mitchell, award committee chairman, at the annual banquet.

At the banquet that evening Julian E. Tobey, general conference chairman, presided. Mr. Tobey is president of Appalachian Coals Inc. Highlight of the banquet was the presentation of the Percy Nicholls Award for 1959 to Homer H. Lowry, noted fuels consultant and author. Presentation was made by David R. Mitchell, chairman of the award committee. Following the award, Ernest S. Fields, president of Cincinnati Gas & Electric Co., spoke on *The Ohio River and Power Development*. Entertainment by Marian Spellman completed the evening.

On Thursday the luncheon presented guest speaker Frederick W. Giesel, business manager for the *Cincinnati Post and Times Star* on the subject of Black Africa. Raymond E. Salvati, chairman of the Coal Division and president of Island Creek Coal Co., presided.

Technical sessions were held in the Pavilion Caprice. Co-chairmen on Wednesday morning were H. E. Mauck, general superintendent, Olga Coal Co., and W. Butler, district sales manager, Babcock & Wilcox Co. Speakers were Charles P. Blair, George W. McCaa, and Martial P. Corriveau. In the afternoon H. B. Lammers, chief engineer, Appalachian Coals Inc., and George R. Ritchie, coal traffic manager, Chesapeake & Ohio R. R., were co-chairmen. They introduced W. L. Sage, J. B. McIlroy, James Jonakin, R. T. Reese, and and J. F. Cotter as speakers. On Friday Carroll F. Hardy, managing director of Bituminous Coal Inst., and John Sinica, district sales manager of Combustion Engineering Co., were co-chairmen. Papers were presented by Arthur S. Maynard, A. L. Barrett, and Myron W. Mellor.

During the banquet Glenn D. Warren, ASME president, addresses the members.

Meanwhile the ladies had an enjoyable program including an Ohio River scenic cruise, a visit to the Taft Museum, and joint activities with the men such as the cocktail party given by Norfolk & Western R. R. before the banquet on Wednesday.

Some of the faces seen at the first session and luncheon are, at left, M. P. Corriveau, speaker; W. Butler, session chairman; C. P. Blair, speaker; and H. E. Mauck, chairman from AIME. The group on the right, back row, begins with W. G. Cornell, Cincinnati Section vice chairman; Robert Baldini; W. C. Bissmeyer, Cincinnati Section chairman who presided at the luncheon; and J. E. Tobey, AIME general chairman. In front are Glenn D. Warren, ASME president; A. A. Potter, H. N. Appleton; and W. E. Keller.

COAL DIVISION NEWS

This month the Coal Division Newsletter has surrendered its space and special heading) to present this excellent open letter from Past-Chairman Holland. The newspaper article he refers to appeared on the first page of the financial section of the New York Times, and made the statement that "Career in Industry Loses Appeal Against Glamour, Pay of Space Fields."

Dear Mr. Ryan:

This letter concerns the article you prepared for the *New York Times* of August 30, 1959, entitled "Engineers Steer Away from Mines." The article provided interesting but disquieting reading. I certainly agree with you up to a point in the reasons you gave for young engineers staying away from the mines. For example, there can be no question but that the ballyhoo over the rocket and space age sciences has had an adverse effect upon the enrollment in the more prosaic branches of engineering including mining. I believe, however, that some of the statements in your article do not represent conditions as they actually exist in the mining industry today. For example, the following statement appears: "During the recent recession many mining engineers—and not the newcomers alone—were laid off." Actually this school (V.P.I.) has some 230 graduate mining engineers in the field, most of whom are still active in the profession. If we had any large number of mining graduates laid off during the depression the news did not get back to this campus. I have also investigated this particular problem by interviewing authorities concerning it at four other prominent mining engineering colleges— two in the east, one in the south, and one in the west. These people without exception report that they have not had unemployment among their mining graduates during the recent depression or since. Also I would point out that during 1957 the Mining Department at V.P.I. graduated nine mining engineers with their first degree. All were placed and we could have placed three times as many if we had had them available. I am told also by the authorities of the schools with whom I talked that this same situation has prevailed at their school with their graduates during 1957 and since. Therefore, it seems certain that during the recent recession no appreciable unemployment occurred among mining engineering graduates. Furthermore, I am convinced that if a survey were actually made you would find that the unemployment of mining engineers during the recent recession was far less than it was in most of the other recognized branches of the profession.

Other statements in your article that deserve some amplification are "The kids wouldn't mind being exiled to some lonely mine out in the cactus or the jungle if the rewards were commensurate with the hardship" and "The new engineer gets stuck with underground surveying or sampling for months or years." In connection with these statements I would like to make the point first that mining engineers, if not so inclined, do not have to accept positions out in the cactus, jungles, etc. I think if you will take the trouble to look into it that you will find more mining engineers are employed in New York City, for example, than in the entire state of West Virginia, a major mineral producer. Furthermore, large numbers of positions are available in the Pittsburgh district of Pennsylvania as well as in the northern and southern parts of West Virginia, all of which lie close to large, well developed metropolitan areas. The same is true with regard to the Birmingham district of Alabama, the Chicago district of Illinois, as well as the St. Louis district in Missouri and Illinois and the Denver district in Colorado. The same conditions exist also in many other parts of the country. I would say that in the United States today the mining engineer works under about the same conditions of isolation and loneliness that the civil engineer, electrical engineer, and mechanical engineer does and perhaps is in nearly as good a shape in this regard as is the chemical engineer.

With regard to the long period of underground surveying and sampling, mining graduates are supposed to do, you must remember that all graduates are not endowed with the same aptitude for advancement. Consequently, some are certain to do the less desirable parts of the job for longer periods than others are. On the other hand, it is doubtful you will find a single branch of engineering in which the advancement to responsible positions for those qualified is as rapid as it is in mining. Also due to the rather low number of graduates that we have had during the past the competition in the mining industry for the jobs at the top is much less severe than it is in many other industries including those connected with rocket and space age developments.

Now with regard to Mr. Roger Pierce's comments it should be pointed out that a goodly amount of the enrollment in mining engineering today is due in part at least to the promotional efforts expended by the 29 accredited institutions he mentions. Merely cutting the number of institutions to six supported, in part at least, by the Federal Government (the modern panacea for all our difficulties) will only serve to decrease these promotional efforts and will probably have the end result of producing fewer mining engineering graduates. His generalization that "Ninety per cent or more of our mining engineers are coming from state-supported schools, not one of which has enough money to put a first class faculty on the campus" is, like most generalizations, largely unfounded in fact when applied to many specific cases. It so happens the writer of this letter for some years served as an ECPD inspector of mining engineering curricula in this country and while it is true that some of our mining faculties are not as strong as others it is also true that many of our mining colleges, state supported or otherwise, have outstanding faculties and excellent facilities for mining education. In this respect our mining departments, schools and colleges are in about the same position as are the faculties and facilities engaged in the education of the branches of the engineering profession.

Salaries earned can be argued about over a long period without reaching an agreement. Citing individual salaries will prove little or nothing. However, surveys made by the National Society of Professional Engineers *Income and Salary Survey 1958* p. 14-15) indicate that the reported earnings of mining engineers compare quite favorably with salaries reported as earned by members of the other branches of engineering at similar experience levels. As a matter of fact, the indications are that mining salaries are considerably higher than earnings of most of the engineering branches showing a smaller percentage decrease in enrollment during recent years.

In closing this letter it seems worthwhile to point out that the mining industry in the United States is a vast one and is one that has many branches, divisions, and segments. A hasty on-the-spot survey stands little chance of locating the major reasons for any particular condition or state of affairs in the industry. In this instance I believe your survey and article have not developed the real causes of the condition you investigated. Your article, however, has pointed up a situation that is serious for the mining industry and, therefore, for the nation as a whole. It seems to me to be high time that a serious, carefully thought out and well planned investigation be made to determine the real reasons causing the decline in the number of engineers entering the mining industries.

Sincerely yours,
Charles T. Holland
Past-Chairman, Coal Div.
Professor and Head of
Mining Engineering, V.P.I.

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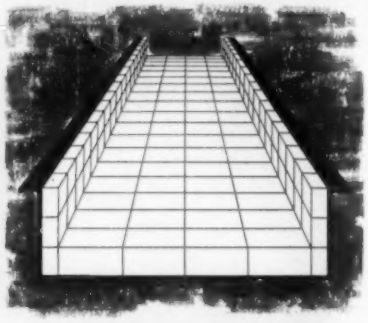

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PORCELAIN DIVISION
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Pacific Northwest

(Continued from page 1252)

Northwest Oil Report.
Paper from Research Dept. of Pacific Power and Light Co.
Paper from Oregon State College, by *George S. Koch, Jr.*
Aerial Mapping and Construction of Topographic Maps: *Leonard Delano*, Delano Studios.

1:30 pm **Metals Branch Iron and Steel (New Fabrication Techniques)**

Explosive Forming Material and Control, paper from E. I. DuPont Co.
Explosive Forming Applications, paper from an aircraft company in California
Chemical Milling: paper from Turco Chemical Co.

5:00 pm **Field Trip**
Bonneville Control Center

8:00 pm **Reception**
Portland Art Museum

FRIDAY, APRIL 29, AM

9:00 am **Gold**

Pierre Hines, *Chairman*

Review of the Gold Problems by World and Countries, and Relationship to Gold Production and Reserves: *Donald H. McLaughlin*, Homestake Mining Co.
Gold in International Payments: *M. A. Kriz*, First National City Bank of New York.
Gold in United States Monetary System: *O. K. Burrell*, University of Oregon.

9:00 am **Industrial Minerals**

Tom Waters, *Chairman*

Percentage Depletion: *Glen McDaniel*, Haskins & Sells.
Facilities, Imports and Exports of the Commission of Public Docks: *Thomas Guerin*, Commission of Public Docks.
A Technical Phase of Lime Burning: *Hans Leuenberger*, Chemical Lime Co.

9:00 am **Metals Branch**
Physical Metallurgy (Melting and Casting of Exotic Metals)

Harry Czyzewski, *Chairman*

The Production of Refractory Metals Using the Electron-Beam Technique: *E. F. Baroch*, Wah Chang Corp.
Ingot Quality Vacuum Remelted Uranium Metals from Ceramic Coated Graphite Crucibles: *J. C. Tverberg*, General Electric Co.
A Laboratory Casting Furnace for High Melting Point Metals: *P. G. Clites and E. D. Calvert*, USBM
A Liquid Cooling System for Consumable Electrode-Arc Furnaces: *D. E. Cooper and E. Don Dilling*, Titanium Metals Corp.

FRIDAY, APRIL 29, PM

12:00 pm **Luncheon**

Speaker: *Philip Cortney*, president of Coty Inc.

1:30 pm **Experts' Panel on Gold**

Panel Moderator: *Evan Just*, Stanford University
Participants:
M. A. Kriz
Donald H. McLaughlin
O. K. Burrell
Oscar L. Altman
V. C. Wansbrough

1:30 pm **Industrial Minerals**

Three papers planned

1:30 pm **Iron and Steel (Heat Resistant Alloys)**

Alloy Groups and Mechanical Properties, paper from Battelle Memorial Inst. or Alloy Castings Inst.
Welding and Joining Methods: *Ken Spizer*, International Nickel Co.
Applications: *Mary Dudin*, Standard Oil of California.

7:00 pm **Cocktail Party**
Speechless Banquet
Entertainment

SATURDAY, APRIL 30, AM

9:00 pm **Field Trip**

Bus Trip and Boat Trip of Commission of Public Dock's Facilities.

WAAIME Plans

(Continued from page 1251)

Norris. Mrs. Boyd McCoy is the chairman. That evening the wives will join the men for the Annual Banquet at the Statler. Mrs. Stuart Levinson and Mrs. Thorne Lloyd will be on hand at 7 pm to be your hostesses.

In addition, Mrs. R. J. Mechin is hospitality chairman; Mrs. Stuart Levinson is in charge of publicity; Mrs. Rodger Sherman is treasurer; and Mrs. Arnold Miller is secretary.

Committee members not mentioned above who are working diligently to support these chairmen are as follows: Mrs. Thomas Allen; Mrs. W. C. Bowden, Jr., Mrs. Oliver Bowles; Mrs. James Boyd; Mrs. A. A. Brown; Mrs. R. A. Cattell; Mrs. E. P. Chapman, Jr., Mrs. Coburn; Mrs. R. D. Coombs; Mrs. H. E. David; Mrs. S. H. Dolbear; Mrs. J. P. Dyer; Mrs. H. W. Hardinge; Mrs. R. C. Hills; Mrs. R. W. Hyde; Mrs. Evan Just; Mrs. L. W. Kemp; Mrs. Alan Kissock; Mrs. F. E. Kudlich; Mrs. Herbert Kursell; Mrs. A. H. Miller; Mrs. H. R. Norsworthy; Mrs. D. J. Pope; Mrs. J. A. Poulin; Mrs. R. W. Rowen; Mrs. E. H. Thaete; Mrs. L. E. Thelin; Mrs. G. M. Wiles; and Mrs. C. Holmes.

Around the Sections

• The **Connecticut Section** met on September 23 for an afternoon tour of the Bridgeport plant of Carpenter Steel, followed by a dinner meeting at the University Club. The topic for discussion was high alloy steels.

• The **St. Louis Section** held their opening fall meeting on September 11 at the Hotel York. James Wescott, prospecting superintendent of A. P. Green Fir Brick Co., discussed *Prospecting for Refractory Raw Materials.*

• A letter from the **Philippine Section** may give other Sections a new idea on fund raising:

Dear Sir:

At our last meeting in Baguio, August 1, the members had the opportunity to visit a shaft sinking operation at the Acupan Mine of Benguet Consolidated Inc. This is an 18-ft. dia. circular concrete lined shaft. (See pictures below)

That afternoon, a meeting was held at the Mine Staff Mess. Since our finances are now in fair shape, it was voted to return AIME check C-20067 for $100 as our initial contribution to the United Engineering Center. As more of these rebates are made available, I would suggest that you hold the remittance as I believe the members will be agreeable to the same procedure for sometime. It is also possible, if the Central Bank will permit, that the Section may make additional remittances from local funds.

Yours very truly
J. W. Pickard
Chairman

• The **Southern Sierra Subsection,** Southern California Section, held their final meeting of the 1958-1959 program on June 15. New officers elected at the session are as follows: chairman, John E. Martinson; vice chairman, James D. Mulryan, Jr.; and secretary-treasurer Richard E. Chamberlain. The program was a slide presentation by Harrison P. Gower on his trip to Russia.

• On May 22 the Old Timers Club, Pittsburgh, gave the annual award to the outstanding senior graduating in mining engineering at Virginia Polytechnic Institute. Okley B. Bucklen, vice president of the **Burkhart Mining Society,** AIME Student Chapter, received the reward for his enviable record. Mr. Bucklen is now employed by The North American Coal Corp. in Cleveland.

• The dinner meeting of the **San Francisco Section** featured Robert H. Raring as guest speaker on the subject of uranium hydrometallurgy and future gold plants. The meeting, on October 14, was open to general discussion.

• The **Ajo Subsection,** Arizona Section, officers this year are as follows: T. R. Herndon, president; F. W. Denny, vice president; and E. T. Seaberg, financial secretary.

Meetings during the spring included a paper on drilling methods and equipment at the New Cornelia open pit mine, held on March 19 at the Copper Coffee Shop.

On April 9 a dinner meeting was held for high school students interested in engineering. J. D. Forrester, dean of the College of Mines at the University of Arizona, was the speaker. R. E. West gave a short talk on the importance of engineering and introduced Waldo Dicus, superintendent of schools, and Nicholas Paynovich, school principal, and Marion Engle, teacher.

In May they held a picnic, with Mrs. Alice Hoppe and John Coppe in charge.

On October 8, R. Rhoades and W. Keener gave a report on the building fund drive, and a discussion of the National Congress meeting in Denver was presented by Mr. Rhoades, T. B. Hinton, and F. Rickard.

• Joseph C. Rintelen, Jr., showed movies of milling and smelting at International Nickel's mine in Sudbury, Ontario, during the October 14 meeting of the **El Paso Section.**

• The annual dance of the **Mexico Section** was held on October 3, arranged by Engrs. Oscar Chavez, Mario Pena, and W. C. Campbell.

The regular meeting, October 13, featured the film *Del Petroleo Al Hule* presented by the U. S. Bureau of Mines.

• The **Tri-State Section** welcomed A. B. Cummins, President-Elect of SME, as an unofficial guest at their meeting October 9 in Baxter Springs, Kan. Andrew Bailey, Section chairman, introduced Mr. Cummins, and Earl Gordon, program chairman, introduced Paul Thompson who showed slides of Morocco.

• The **Lima, Peru, Section** met on September 16 and heard guest speaker Richard R. Knobler, chief metallurgist for Mauricio Hochschild y Cia., S. A.

• *Some Things Mining Management Should Know About Doing Business Abroad* was the subject covered by Joseph B. Brady at the **New York Section** meeting on October 22. Mr. Brady is director of Foreign Property Div., National Foreign Trade Council.

Personals

W. L. DOWDEY

P. O. RICHTER

Wayne L. Dowdey, formerly manager of Eimco's Southern District, has been appointed general sales manager for the corporation. **Paul O. Richter,** vice president of The Eimco Corp., has been named general manager of the Filter Div.

Robert W. Parkinson has accepted a teaching position in the science department of Southwest Missouri State College as an instructor of geology. He is now in Cape Girardeau, Mo. Before he was in Easton, Conn.

Herbert E. Haymaker, sales engineer for Fairchild Aerial Surveys Inc., transferred to Denver as regional representative.

L. B. Philippi has been named head of a new truck sales division of LeTourneau-Westinghouse Co. Mr. Philippi was formerly sales manager with White Motor Co.

Vulcan Materials Co. has announced the appointment of **Harold H. White** as director of blasting practices and explosives research.

W. W. BLOOD

W. N. MATHESON

Appointment of **William N. Matheson** as executive vice president of Oliver Iron Mining Div., U.S. Steel Corp., has been announced. At the time of his promotion, Mr. Matheson was Oliver's vice president in charge of operations.

William W. Blood, who has been district manager of Roberts and Schaefer for the past ten years, has resigned to enter Virginia Theological Seminary as a pre-ministerial student.

Lars Osen has accepted the position of assistant superintendent for American Smelting and Refining Co. Formerly he was a student at the University of North Dakota.

Chester M. F. Peters completed a five month assignment as consultant to Brown Engineers Inc. He located and test drilled quarry sites for the fill and aggregate for the Dammam Pier project in Saudi Arabia. He spent a month in Sudan investigating gold property before returning to New York.

Ned. E. Nelson, for the past 4½ years a representative of the U. S. Geological Survey working with the Defense Minerals Exploration Administration and the successor agency, O.M.E., has resigned from the Survey to engage in private practice.

Benjamin M. Holt has been named sales manager for the engineering and construction division of the Southwestern Engineering Co.

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CHANGING YOUR ADDRESS? Don't forget to notify us six (6) weeks before you move, if possible, to insure uninterrupted receipt of your publications and correspondence. Please fill in the form below and send it to: J. F. Lynch, Asst. Treasurer AIME, 29 West 39th Street, New York 18, N. Y.

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Old Address .....

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PERSONALS: Please list below your former company and title and your new title and company (or new work) for use in MINING ENGINEERING. (Copy deadline for personals items is six weeks before date of issue.)

Name .....

Former Company .....

Former Title ..... Length of Time There .....

New Company .....

New Title ..... Date of Change .....

.....

Any recent activity that would be of interest to members:

.....

.....

C. THOM

D. S. TAYLOR

Clarence Thom, director of the Denver Equipment Co.'s ore testing division for nearly 25 years, has become consulting metallurgist for the company. In a recent transfer from the New York City office, **C. T. E. Beardsley** has been appointed manager of the new sales and service office, Bluefield, W. Va.

Hugh C. Colman has been appointed dust and mine gas engineer for the state of New Mexico. He will work out of the Albuquerque office of the state inspector of mines.

Donald S. Arnold has been named manager of research at American Potash & Chemical Corp.'s main plant at Trona, Calif. He will succeed **Donald E. Garrett** who has resigned from the company to go into business for himself.

Appointment of **D. S. Taylor** as president and **C. L. Randolph** as vice president of U. S. Borax Research Corp. has been announced. Dr. Randolph will be in active charge of operations at the laboratory at Anaheim, Calif.

C. T. E. BEARDSLEY

C. L. RANDOLPH

Leo E. Read has been appointed general manager of the International Salt Co.'s Detroit and Cleveland mines and **John L. Ryon, Jr.,** has been moved from the position of assistant manager to manager of the Detroit mine.

John C. Orth has been appointed application engineer in the processing machinery department of Allis-Chalmers Mfg. Co.

Stephen F. Dunn has resigned as vice president of the National Assn. of Manufacturers in charge of government relations to accept the presidency of the National Coal Assn.

Appointment of **Keith E. Chave,** for the past seven years research geologist with California Research Corp. in LaHabra, Calif., as assistant professor of geology at Lehigh University was recently announced.

L. K. Lepley is now employed by the U.S. Navy hydrographic office at Suitland, Md., as a civil engineer-geologist.

Stefan Wieklinski has completed his contract with Comibol where he was chief geologist of the Siglo XX mine in Bolivia, and has moved to Buenos Aires.

James C. Tourek has been appointed vice president for engineering of Vitro Engineering Co. He succeeds **Sidney M. Stroller** who will be retained by Vitro as an engineering consultant.

C. E. Graves, Jr., resigned as mine engineer, Idorado Mining Co., Ouray, Colo., and has accepted employment as engineer with the Atomic Energy Commission facilities division of Holmes & Narver Inc. He is on temporary assignment at the Carey salt mine in Winnfield, La. where the A.E.C. is conducting Project Cowboy.

Edward R. Borcherdt has retired as director of mining research at the Anaconda Co. and has formed a new mining consulting partnership with **C. DeWitt Smith.** The main office will be at 369 Pine St., San Francisco, while Mr. Smith will

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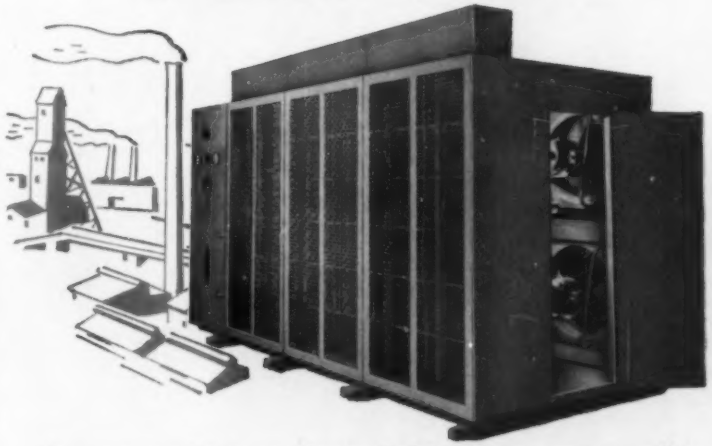

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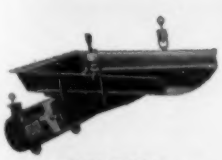

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personals

continued

continue to maintain an office in Lincoln, Mass. Consultation will be offered on mine management and operation, mine plant planning and layout, and in evaluating mining properties.

M. L. Shome, formerly chief mining engineer and secretary of the Indian Coal Board for the Government of India, has become consulting mining engineer. He has been with the government for 27 years.

David M. Knowles has moved with his company, Canadian Javelin Ltd., from Montreal to New York, where he will continue to be chief geologist, taking up residence in Princeton, N. J.

J. F. Shaffer was separated from the Air Force and presently is employed by Phillips Petroleum Corp. in Idaho.

Victor A. Haw, for ten years acting chief of the industrial minerals division, Dept. of Mines and Technical Surveys in Ottawa, has become manager of the industrial minerals division of Ventures Ltd. in Toronto.

Gerald E. Rutledge, formerly 1st Lieutenant in the Corps of Engineers, U. S. Army, now is sales engineer in the heavy equipment section, Koehring Div. of the Koehring Co.

L. M. Coffey is in Hong Kong with the Joy International S. A. of Monte Carlo, which is Joy Mfg. Co.'s representative for South East Asia and the Far East.

A. M. Hattingh resigned as mill superintendent with the M. T. D. Mangula Mining Co. and has moved to Ventersdorp in the Western Transvaal where he took over some family interests.

Alberto J. Terrones L. is no longer working for Cananea Consolidated Copper Co. but is in business for himself as consultant in Mexico City.

H. R. Hanley celebrated his 85th birthday with many old friends on hand, including former students, metallurgists, and others who have been influenced by his teaching, as professor emeritus of Missouri School of Mines. A large volume of letters and telegrams carrying greetings from former students round the world was presented to the professor, and a special letter from former President Herbert Hoover conveyed his congratulations.

Peter Sharp has been appointed director and general manager of Dowty Mining Ltd. in Ajax, Ontario. Also appointed a director of the North American office was **Michael C. Potts,** mining manager of Dowty Mining Equipment Ltd. in Ashchurch, England, who is responsible for liaison between the English and Canadian mining companies.

M. C. POTTS J. W. FAUST

J. W. Faust of Silver City, N. M., and **W. H. Lowe, Jr.,** of Greenwich, Conn., have been elected vice presidents of Hydrometals Inc. Mr. Faust has been general manager of the Peru Mining Co. and Mr. Lowe has been assistant to the president of the parent corporation.

T. V. Canning, formerly assistant project manager for Catalytic Construction Co., now is vice president of Steel Structures of Colorado.

Ronald W. Clark, formerly in charge of the soil laboratory for the Corps of Engineers, U. S. Army, now is civil engineer assistant for the City of Los Angeles and is looking for investors for a Colorado lead mine.

Eugene T. Moroni, who had been general superintendent for Coal Processing Corp., subsidiary of Old Ben Coal Corp., now is assistant to the vice president of the parent concern.

Tom T. Brown has been promoted from assistant district sales manager to manager of chemical sales section, explosives department, E. I. DuPont de Nemours & Co. Inc. He will be located in Wilmington, Del.

Donald O. Rausch is now design engineer for Kennecott Copper Corp., Western Mining Div. He had been mining engineer for Dravo Corp., shaft and tunnel department. Now he is located in Murray, Utah.

J. C. Shoemaker, formerly plant superintendent for Southern Illinois Mining Co. in Rosiclare, Ill., now is manager of Mico M & M Co. in Marion, Ky. doing barite mining.

Jerome B. Carr, formerly student at St. Louis University, presently is a surveyor for Barnes Engineering Co. and expects to return to school in February.

Thomas N. Walthier, Bear Creek Mining Co., has become district geologist. He had been assistant to the president.

Thomas G. Murdock, first secretary at the American Embassy in Ankara, Turkey, and regional minerals officer, spent a vacation in the U. S. and returned to Turkey in early November.

R. E. Barthelemy, consulting mining engineer who was the first to apply successfully electrical high tension separation to the beneficiation of iron ores, has accepted an assignment for the M. A. Hanna Co. to evaluate beneficiation methods under pilot plant study at Carol project in Labrador.

Richard Quirk, formerly assistant manager of the mining department, now is manager of the mining division for The Glidden Co. A new plant is being built in New Jersey under his charge.

Bruce Karinen has accepted a new position with Union Carbide Nuclear as a geologist in Uruvan, Colo. He has moved from Butte, Mont.

Roderick R. Asher of Cerro De Pasco Corp. has been transferred from exploration work in Tucson, Ariz. to the position of mine geologist in the San Cristobal mine, Peru.

E. C. Young, who for the past three years has been pilot plant supervisor for Rhoanglo Mine Services Ltd., has become mill superintendent for Louis Moore Gold Mining (Pty) Co. Ltd. in the Northern Transvaal, South Africa.

Donald J. Wolfe has been named manager of sales development for Southwestern Engineering Co.'s Krupp-Renn and Lurgi processes. He has been with the firm for two years, specializing in services to the iron and steel industries.

P. SHARP B. A. SCHEPMAN

Jack W. Pratt and **Berne A. Schepman** have been elected vice presidents of the process engineers division of The Eimco Corp. Mr. Pratt was eastern sales manager of the process sanitary division, located in Palatine, Ill. Mr. Schepman is located in the sales and engineering offices in San Mateo, Calif.

Samuel H. Dolbear, president, and **Parke A. Hodges,** vice president of Behre Dolbear & Co., consultants in the mineral industries, are engaged in mine valuation in California. **A. F. Banfield,** geologist for the firm, is in Jutland cooperating with Danish Government officials in the study of extensive salt deposit.

John R. Welch has completed three

years as chief of the minerals division, U.S.O.M. in Nepal, and has recently returned to the U. S.

Arnott J. Lee, Joy Mfg. Co., has been transferred from his position of manager, Government office in Washington, to district manager of the Chicago mining and construction division.

Arthur J. Weinig, Jr., has been named chief engineer of the U. S. Borax and Chemical Corp. He will be responsible for the Carlsbad operations of the corporate engineering department.

H. B. Coulter has been doing consulting work in California since his retirement from Dorr-Oliver in 1956. He recently moved to Denver where he will continue his practice as technical consultant.

W. H. LOWE, JR.

J. W. PRATT

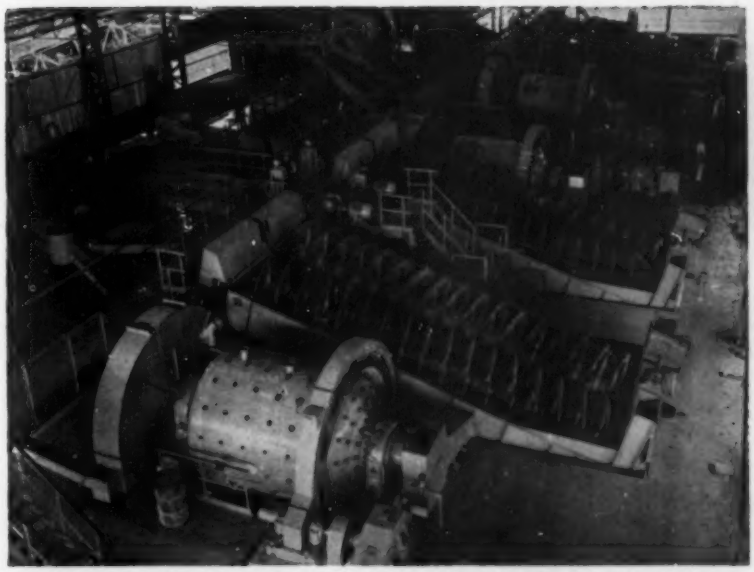
Jack Pate has transferred to Ontario from New Mexico in his position of chief chemist in that operation for The Anaconda Co. Now he is working for Anaconda Iron Ore Ltd. in Port Arthur, Ont. under **J. B. Knaebel,** former manager of the New Mexico operations.

Ivor G. Pickering has been named general manager of Kennecott Refining Corp.'s new electrolytic refinery south of Baltimore, Md. Mr. Pickering was promoted from his position of project manager.

Albert I. Edwards has been assigned to Allis-Chalmers Mfg. Co.'s processing machinery department as a special representative. He has been a specialist in the Mid-Atlantic region since 1949. In another promotion, **John K. Gibson** has been appointed supervisor of cement machinery sales for the firm. He had been application engineer.

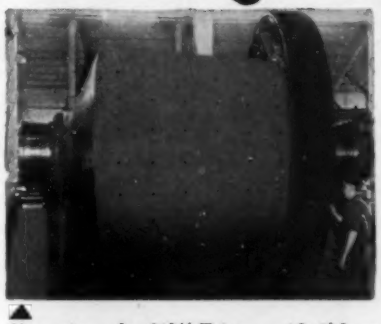
Thomas F. Courthope, general manager of the International Salt Co.'s Detroit and Retsof, N. Y., mines since 1919, has retired after a distinguished career with the company. **Stanley Martin,** manager of Retsof, will now be in full charge of the mine.

Herbert J. Mayer, executive vice president of Western Machinery Co., has been elected a partner of the Edward R. Bacon Co. of San Francisco and will assume the position of general manager of the company. He will also continue as a director of Western Machinery Co. and as executive vice president in charge



Shown here are four Hardinge 9-3-6-8 Tricone Mills grinding sulfide copper ores and mixed ores in a concentrating plant in the Belgian Congo, Africa.

CORRECT BALL SEGREGATION in the Hardinge TRICONE MILLS



Shop view of a 10½′ Tricone with 9′ long tapered shell.

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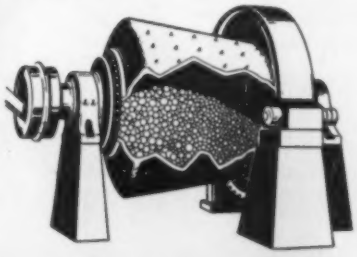

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personals

continued

of the company's machinery distribution business.

Chester E. Grigsby, vice president and director of American Steel Foundries and general manager of its transportation equipment division, now is head of this division, succeeding **Charles L. Heater** who has retired. Mr. Grigsby has been with American Steel Foundries for 36 years.

S. W. F. Patching, formerly head of the mineral dressing group for the Atomic Energy Authority at Harwell, has joined Baker Perkins Ltd., Westwood Works, Peterborough, England, as manager of their new mineral processing department.

Thomas H. Lentz, a former research engineer at Michigan College of Mining and Technology, has joined Archer-Daniels-Midland Co.'s development department as a development engineer.

John H. Dismant, formerly associate professor of mining and metallurgy at Texas Western College, El Paso, Tex., has accepted the post of professor of mining engineering at the University of North Dakota and Grand Forks. During the summer he was consulting engineer for the U.S. Air Force in Oklahoma.

John H. Bassarear has become assistant mill superintendent for Pima Mining Co. in Tucson, Ariz. after eight years with National Lead Co. in New York, most recently as mill superintendent in Tahawus.

Gordon Deutsch, formerly mining engineer for Freeport Sulphur Co., now is production engineer with National Gypsum Co. in Bellefonte, Pa.

Robert W. Stephens has been promoted from senior engineer to plant superintendent for Kaiser Aluminum & Chemical Corp. in Midland, Mich.

C. R. Sacrison, formerly chief engineer for Consolidated Coppermines Corp., now is mine superintendent for Wells Cargo Inc., mining phosphate under contract for Central Farmers Fertilizer Co., Georgetown, Idaho.

R. N. Whisenant of Hercules Powder Co. has transferred from Pittsburgh where he was special representative, to San Francisco where he now is assistant manager.

John W. Finklang recently completed a year of special geodetic training sponsored by the Air Force at Ohio State University and has advanced from cartographer to geodesist, located in St. Louis.

George F. Reed has been consulting on gold-silver operations in southwestern Nevada after leaving Wah Chang Mining Corp. where he was assistant general manager. Now he has joined Sonoma Quicksilver Mines Inc. as resident manager in Guerneville, Calif.

Alan C. Teasdale, formerly assistant manager of Metal Recoveries Pty. Ltd. now is mining engineer for Australasian Civil Engineering Pty. Ltd. in Potts Point, New South Wales, Australia.

C. Dudley Blancke, Jr., has joined Reynolds Aluminum Co. as mine engineer after five years as production engineer for Jefferson Lake Sulphur Co.

Joseph F. Brown has resigned from the U.S. Bureau of Mines in Salt Lake City and is employed as a mining engineer with the Mining and Milling Div. of Phillips Petroleum Co. in Grants, N. M.

After graduating in metallurgy from the Royal School of Mines, London University, **C. B. Gee** has taken the post of learner mine official with Nchanga Consolidated Copper Mines Ltd. in Northern Rhodesia.

D. E. Metheny has recently been transferred from the San Francisco office of General American Transportation Corp. to their East Chicago, Ind. laboratory where he will be manager.

I. R. M. Chaston has been awarded the William Frenchville Prize for 1959 by the Council of the Institution of Mining and Metallurgy. He is presently in the Dept. of Mines, research division, in Malaya.

J. J. Dworatzek has joined Quemont Mining Corp. Ltd. in Noranda, Quebec, Canada, as assistant mill superintendent after leaving Gaspe Copper Mines Ltd. where he was a mill engineer.

James H. Hunter became president and general manager of Ace Concrete Co. when Hecla Mining Co., where he was mill superintendent, purchased the firm. He is located in Spokane.

Frank R. Milliken, executive vice president and director of Kennecott Copper Corp., heads the fund raising campaign of the Foreign Policy Assn. which started in October.

Thomas B. Rees has been appointed purchasing agent of the Utah Copper division of Kennecott Copper Corp. **W. K. Field** had been acting purchasing agent.

J. Connell, formerly undergraduate student at Montana School of Mines,

now is a graduate student in the mining department at Pennsylvania State University.

R. D. Burns, who has been a Ph.D. student at Washington State University and during the summer a resident geologist for Calumet & Hecla Inc. in Calumet, Mich., now is a geologist with Stanleigh Uranium Mines Ltd.

C. D. Vaughan, Jr., formerly mining engineer for E. J. Lavina & Co. in Philadelphia, has transferred to the post of project manager for a new plant being built at Freeport, Texas, for the production of periclase.

Ernest E. Thurlow has become chief mining geologist for Northern Pacific Railway Co. in St. Paul, Minn. He had been chief geologist with Marcona Mining Co. in San Juan, Peru.

Conrad W. Thomas, mining consultant, recently visited Europe, Asia Minor and Africa examining mineral prospects in France, Belgium, Italy, Greece, Turkey, and several areas in Africa.

J. S. BROWN

J. P. MORGAN

John S. Brown, chief geologist, St. Joseph Lead Co., retired October 1 after 34 years of service. Starting at Joplin in 1925, Mr. Brown was transferred to New York and again to Missouri in 1947. He plans to settle in Towson, Md. **Frank G. Snyder** will succeed Mr. Brown in southeast Missouri.

John P. Morgan, formerly associate professor at the University of Adelaide, now is professor of mining engineering at the University of New South Wales. Professor Morgan has done recent work on dynamic shocks in mine hoisting systems.

Augustus B. Kinzel, Past-President of AIME, and vice president in charge of research of Union Carbide Corp., has been named the recipient of the Industrial Research Inst. Medal for 1960.

G. W. Bergman has been transferred to St. Louis Mo. with Joy Mfg. Co. as assistant district manager.

W. B. Boggs retired after 21 years service with Noranda Mines Ltd. in Noranda, Quebec. He moved first to Garden City, and then to Tucson, Ariz., where he is doing some consulting work.

Bernard F. Brady, formerly metallurgist for St. Joseph Lead Co., now is assistant mill superintendent for

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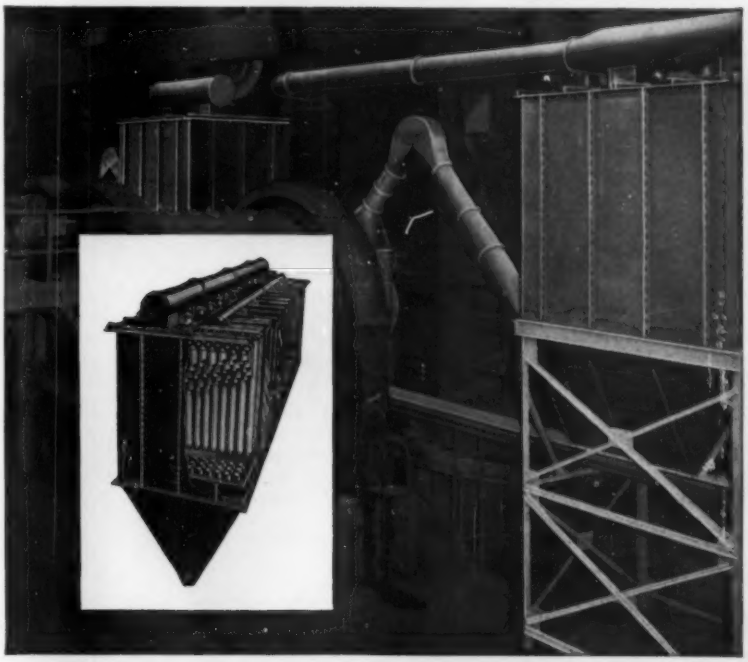

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personals

continued

Compania Minera Aguilar S. A. in Argentina.

Richard L. Brittain became production engineer for Hidden Splendor Mining Co. in September, after eight years with American Zinc, Lead & Smelting Co. as superintendent. He is now located in Salt Lake City.

Paul L. Cloke was a postdoctoral research fellow at Harvard University until September when he became assistant professor at the University of Michigan.

Hugh Douglas, a member of American Overseas Petroleum Ltd., has moved from Ankara, Turkey to Tripoli, Libya, in the same position as staff geologist.

J. S. Fryberger received his M.S. degree in geology from the University of Oregon and joined Robinson & Roberts as geologist, located in Tacoma, Wash.

Earl R. Hoskins is in deep sea diving school at Indian Head, Md., with the U.S. Navy. He had been a sales engineering trainee with Goodman Manufacturing Co.

John C. Hagen spent 18 months as senior geologist for Mineraco Hannaco Ltda., in Bela Horizonte, Brazil, while the firm was completing its iron exploration program as agent for St. John D'el Rey Mining Co. Ltd. Now he is senior geologist, Ozark Ore Co., Iron Mountain, Mo.

Emerson J. Lyons is assuming expanded duties in new product development for General American Transportation Corp. in his position as manager of the turbo-mixer division.

H. C. Laird has been manager of mining for the past three years at Heavy Minerals Co., subsidiary of Crane Co., until the parent company sold its interest in heavy minerals and transferred Mr. Laird back to Crane Co. He is presently manager of oil industry sales, with his home in River Forest, Ill.

Pierce D. Parker recently finished a year of academic work under an N.S.F. fellowship and submitted his Ph.D dissertation, He had been geologist for Anaconda and now works for American Metal Climax.

Zell Peterman received an M. S. degree from the University of Minnesota and is working toward a Ph.D. in geology at the University of Alabama.

David L. Starbuck, member of Joy Mfg. Co., formerly was assistant to product manager and now is sales engineer with all of New Mexico and west Texas as his territory.

H. E. Wittenberg, Jr., joined The Anaconda Co. as assistant research engineer in September after working for Kaiser Steel Co. as metallurgical assistant. He is in Anaconda, Mont.

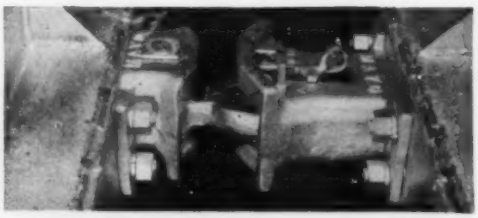
Peter F. Zimmer, who had been a student mining engineer at Lehigh University, and an engineer at Kennecott Copper Corp., Salt Lake City, now is on leave of absence serving as 2nd Lieutenant in the U.S. Ordnance Corps. in Aberdeen, Md.

Jan Bowman, formerly assistant superintendent at American Smelting & Refining Co.'s Tacoma smelter, now is plant engineer at the Natividad plant of Kaiser Aluminum & Chemical Co. in Salinas, Calif.

John C. Nigro graduated from Michigan College of Mining and Technology last June and is research engineer at the Inst. of Mineral Research.

Harold E. Rowen has been elected a vice president of McDowell Co. Inc. in Cleveland. He will have executive responsibility for all the Dwight-Lloyd activities of the company. Mr. Rowen joined the firm in 1955 as general manager of the Dwight-Lloyd division.

NEW, SAFE and AUTOMATIC



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Obituaries

Robert Wilkes Baldwin

An Appreciation By
Arthur A. Brant

Robert Wilkes Baldwin (Member 1954), assistant manager of Newmont Exploration's Geophysical Dept., died Sunday afternoon, July 26, 1959, some hours following a helicopter crash in an abortive landing attempt on Gilman Glacier, several miles north of Mount Crillon, Alaska.

Mr. Baldwin was born in Toronto, Canada, and graduated from Upper Canada College boys' school, after which he served with the Royal Canadian Air Force as a radar officer in the Near East and the United Kingdom. He was awarded the B.Sc. degree from the University of Toronto, engineering physics course, in 1949, having achieved honors standing in all four years.

Directly on graduation he joined Newmont's geophysical exploration and development group then being formed. His efforts contributed markedly to the early developments and use of the induced polarization method and to the evolution of the rigidly attached helicopter electromagnetic system, the field and interpretive procedures for which owe much to Bob Baldwin's work.

His induced polarization survey at Cuajone, Peru, with rudimentary equipment, early 1952-1954, outlined sulphides, in part under 500-600 ft of later volcanics, and stimulated the additional drilling that proved the Cuajone ore body of the present Southern Peru Copper Co. group. See MINING ENGINEERING, vol. 11, no. 3, March 1959, pp. 307-314.

With enthusiasm and humor he had carried his work to many lands, the peaks and caves of Peru, the arroyos and valleys of the Southwest and Mexico, the lake chains and tundra of the Canadian Barrens and the rain-drenched humid islands of the Philippines. Personal travel had reached Egypt, Asia Minor, Scandinavia, and Japan.

In June of 1954 at Arequipa, the white city of Peru, Bob Baldwin married Blancha Rivertti and in 1955 returned with her to the United States. His wife and three children: Lawrence, Carmen and Robert, survive.

Bob Baldwin's great strength was his zest, humor, and equitability to the trials, reverses, and uncertainties of exploration life. In a small frame and beneath a quiet manner he packed the indominability of the early pioneer. To him, as but to few, applied Kipling's pointed lines: "If you can meet with triumph and disaster/And treat those two impostors just the same;/And which is more . . . you'll be a man, my son."

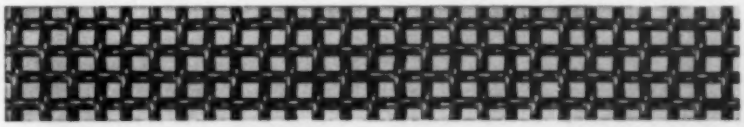
Bob Baldwin has left his example and influence with us here as few have done. We know his bouyant spirit moves onward.

Arthur Fay Taggart

An Appreciation By
M. D. Hassialis

Arthur Fay Taggart, professor of mineral engineering and Emeritus Vinton Professor of Mining at the School of Mines, Columbia University, died on August 22, 1959. With his passing there came to an end one of the most distinguished careers in engineering and in mineral beneficiation.

Professionally Taggart was known to the past, present, and will be known to the future generation of mineral beneficiators as the author of the "ore dresser's bible", i.e. *The Handbook of Ore Dressing* and its successor, *The Handbook of Mineral Dressing*. There is no corner of the earth, no matter how remote, where man extracts the earth's mineral wealth, where one will not find a copy of one or the other of these two books. They have been translated into many languages—German, Russian, Japanese, etc. A "Taggart" was, is, and will be standard equipment for any mining or mineral engineer traveling overseas no matter how limited his luggage. The unique role of these books is



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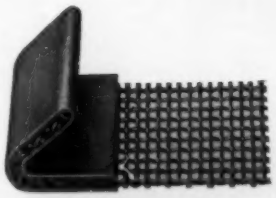

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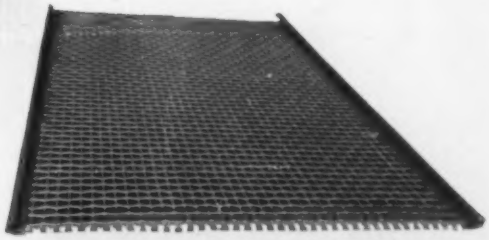

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based on a variety of factors. First, they are complete and exhaustive compendia of practice as of their date of issue. Then in a series of sections each dealing with a unit operation of beneficiation, the component parts of concentration are exhaustively examined. Applicable definitions introduce these sections, followed by a discussion of principles which rationalized the operation and which in many cases gave the only comprehensive explanation found in the literature. This is followed by functional and comparative descriptions of equipment, their performance and examples of their use. Perhaps the most unique feature of these books is the carefully tested speculations appearing in the form of suggestions for improvement of design, performance or understanding dispersed throughout the books. Only an actively inquiring mind, coupled with profound understanding and a fertile imagination could have produced such a wealth of ideas. One ventures to predict that these will form the bases of many researches and publications of the future.

But there is more to the "Taggart bibles" than their utility to the practitioner; they are the embodiment and the evidence of the conversion of the art of ore dressing into the technology of mineral beneficiation. His insistence on the "how" and "why" has done more to spur technological development in beneficiation than is generally recognized. Particularly is this evident in his technical publications and particularly with respect to the theory of flotation. His willingness—nay his insistence—on taking a position before all the facts were in was a challenge to his contemporaries. His broad generalization that the surface reactions of a collector were controlled and therefore predicted by the solution reactions of the collector and the relative insolubility of the reaction products, was the signal for an intellectual controversy which spanned the world for many years and stimulated a wealth of research, the outcome of which is our present understanding of flotation. It matters little that his early theory has been modified and will be modified again and again as our facts increase; the stimulus of his ideas and his forceful personality has left its mark. Taggart was the first to admit that a theory is at best an ephemeral thing for it can be no better than existing knowledge and complete knowledge is unattainable. To the faint-hearted who pleaded for deferment of the rationalization or the generalization, Taggart, sometimes patiently and more often scathingly pointed out that it is the function of a good engineer to make a decision or take a position even when he was unhappy with the paucity of facts—the veriest tyro can make a decision with all the facts in hand but by then his competition has left him far behind.

As a teacher, Taggart had few peers. His approach was not to teach the facts of his subject—except incidentally—but to teach the application of scientific method and of the fundamental principles of science. To him a ball mill was not a piece of ore dressing equipment but a poor and preliminary answer—to be improved upon by his students—to the problem of breaking ore to produce liberation of the valuable minerals from the gangue. Everything was a problem, at first poorly discerned by the student but finally sharply focused by a series of penetrating questions. Then followed an analysis of the problem into its component parts and these parts in turn analyzed into their constituents until they were of manageable proportions and unanswerable. With the answers in hand a synthesis of the partial answers into an over-all answer was made. He saw to it that no complete answer was ever given so that the student always carried away with him tantalizing questions which might one day stimulate him to independent work and thereby to contribution of new knowledge to his profession.

He demanded of his students a goodly measure of proficiency in the art of communication, both oral and written. As he often said, the possession of new knowledge carried with it the responsibility of communicating it to one's professional contemporaries. Towards this end, he insisted on written reports which were read meticulously and constructively criticized in such detail that the criticisms often exceeded in length the report itself. Couched as they were in terse and penetrating remarks, the criticisms were so devastating that no student could long remain immune. The superficial veneer of knowledge which students so frequently acquire was soon ripped away and their ignorance exposed. But with it came the realization that it is the fate of a man to be ever ignorant and that education is a life-long process.

As an educator, Taggart was responsible for establishing ore dressing as a separate curriculum at Columbia. Then by the inclusion of non-metallic minerals this was enlarged into mineral dressing. Finally and as a result of the conviction that mineral dressing was too narrow a specialization not meeting the needs of flexibility imposed by a rapidly changing technology and economy, the curriculum was enlarged into what is known today as mineral engineering. Oddly enough but consistent with his beliefs, while he was segregating and enlarging the specialty of mineral engineering he was simultaneously trying to demolish the departmental barriers at the undergraduate level. As early as 1938, based on an uncanny foresight of the future of engineering, he argued brilliantly and with devastating logic the case for a single undergraduate curriculum which he called general engineering. Unfortunately, the weakness of his case was that his leadership was too far ahead of his colleagues. Yet, it was probably not in vain for cracks are today appearing in the armor of the entrenched segregationists.

As a man, Taggart was a member of a fast vanishing group—the individualists. In this day of team research, committee decisions and diluted responsibilities, he was a breath of fresh air. For himself and his co-workers he set standards of performance and for personal conduct which sorely taxed lesser men. The pace was back-breaking, yet it led to an esprit de corps which will carry on, for there are many men who will proudly identify themselves as one of Taggart's men. To us who have been fortunate enough to have known the man intimately, Taggart's spirit carries on "for the seeds he has sown via the men he has educated have sprouted and will grow and in turn reseed Taggart's ideas and methods in other men." Truly there is no end.

Ralph B. Utt (Member 1949), vice president and executive chief engi-

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neer of the Western Machinery Co., San Francisco, died July 21, 1959, at his home in Belvedere, Calif. He had served his firm for nearly 20 years. He was born in Mansfield, Wash. and raised near Coeur d'Alene, Idaho, where he acquired his lifelong interest in mining. He attended the Montana School of Mines and the University of Idaho School of Mines, graduating there in 1934. He became superintendent of the Glacier Silver-Lead Mining Co. and the Gem Mining Co. Mr. Utt served on the executive committee of the San Francisco Section.

John M. MacLeod

An Appreciation by
H. DeWitt Smith

John M. MacLeod (Member 1953) died on the 7th of September, 1959. He graduated from Queen's University in mining in 1927 and received his early training in engineering and operating at the Brittania Mining & Smelting Co. at Brittania Beach and Brandoro Gold Mines Ltd. at Penticton, both in British Columbia. From 1936 to 1941 he worked his way up to assistant general superintendent at the Howey Gold mine under Edward Futterer.

In 1942 he accepted the position of assistant manager of O'Okiep Copper Co. Ltd. at Nababeep, Cape Province, Union of South Africa. On his way to this new job his boat was torpedoed off Trinidad. In 1953 he was made general manager at O'Okiep, and worked literally until the day of his death.

John MacLeod was an ideal manager for a mine in a remote locality, for he, along with his delightful wife, took an interest in every man, woman, and child on the job. He was fair and honest and sympathetic in his human relations, but a tough Scot for all that.

Necrology

Date Elected	Name	Date of Death
1932	John M. Bush Senior Member	July 4, 1959
1935	Raymond H. Hobrock	Sept. 10, 1959
1945	Leslie W. Householder	July 12, 1959
1942	J. R. Kenney	Unknown
1923	Robert Livermore Senior Member	Sept. 26, 1959
1953	J. M. MacLeod	Sept. 7, 1959
1943	H. C. Meyer	Unknown
1916	A. H. Richards	Aug. 30, 1959
1943	J. A. Rigg	Sept. 21, 1959
1945	C. G. Sheldon	Sept. 16, 1959

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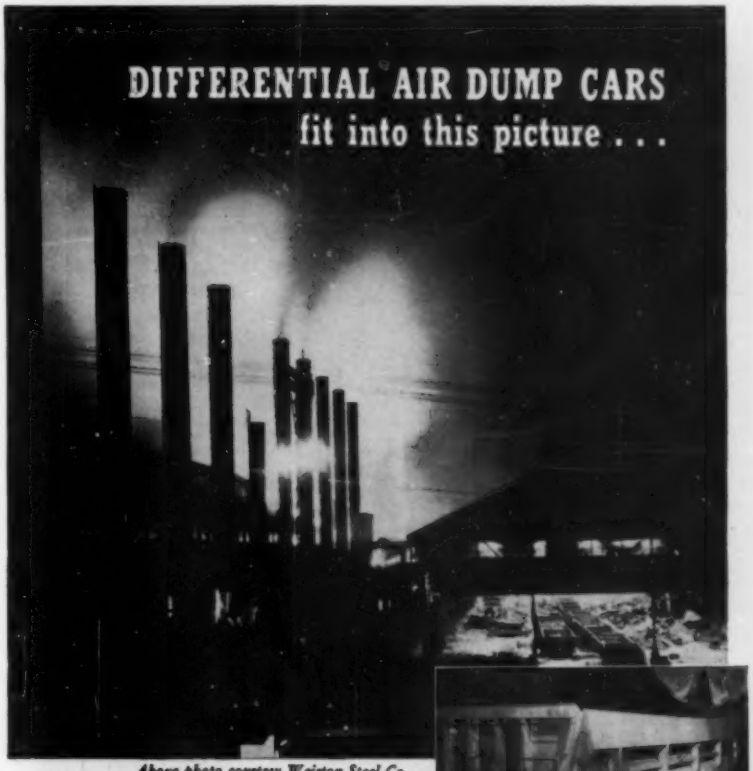

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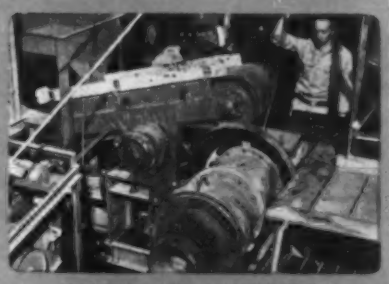

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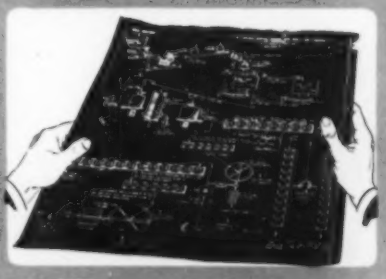

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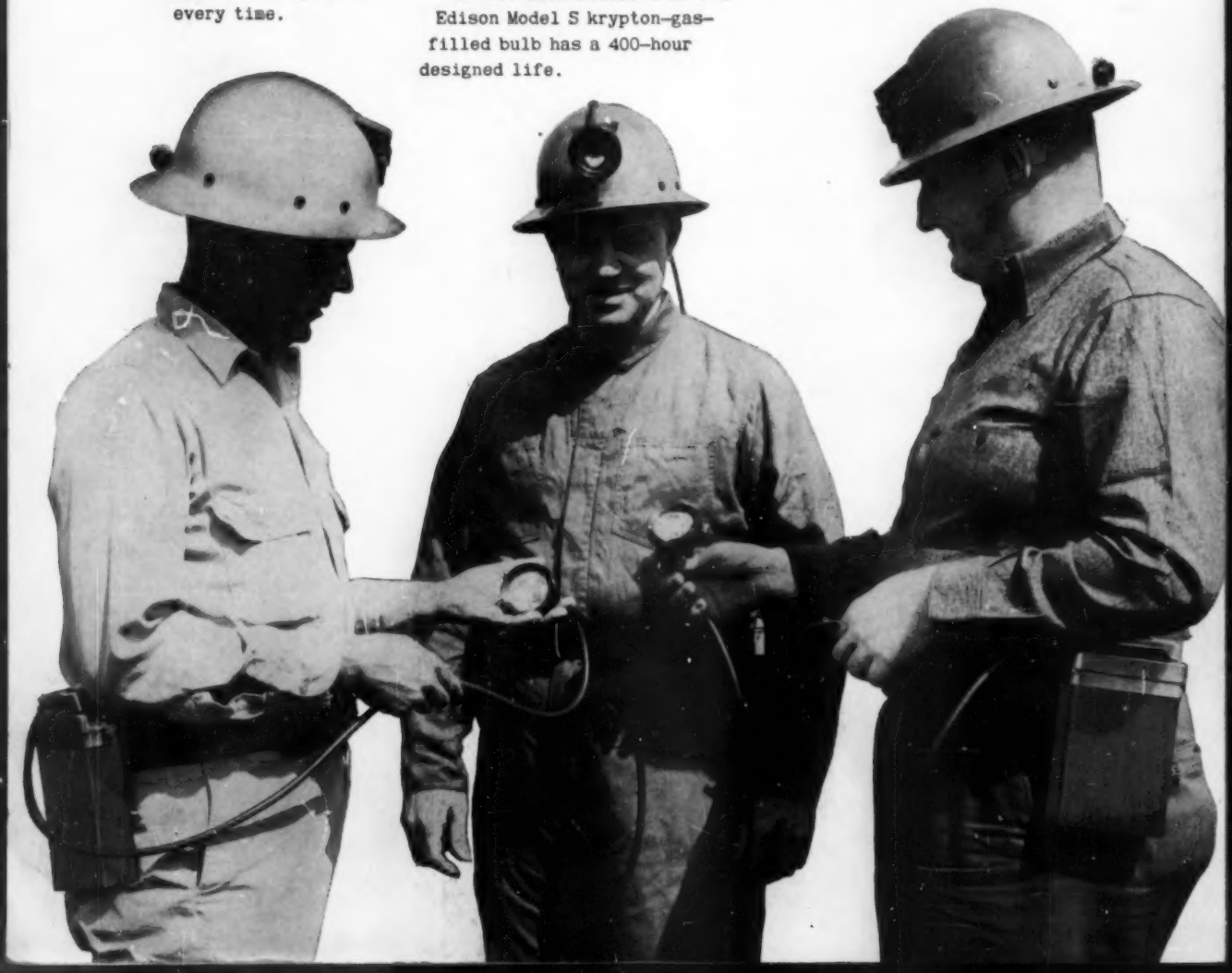
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